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PROCEEDINGS
OF THE
TWENTY-SEVENTH ANNUAL MEETING

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PART I. COMMITTEE REPORTS
NEW AND REVISED TENTATIVE STANDARDS
LIST OF STANDARDS AND TENTATIVE STANDARDS

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SUMMARY OF THE PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL MEETING

ATLANTIC CITY, N. J., JUNE 24–27, 1924

The TWENTY-SEVENTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the Chalfonte-Haddon Hall, Atlantic City, N. J., June 24–27, 1924. The following is an analysis of the attendance at the meeting: Members in attendance or represented, 719; guests, 143; total, 862; ladies, 206. The corresponding statistics for the Twenty-sixth Annual Meeting are: Members in attendance or represented, 704; guests, 154; total, 858; ladies, 193.

FIRST SESSION—TUESDAY, JUNE 24, 2 P. M.

Symposium on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys

(Held simultaneously with the Second Session)

President Guilliaem Aertsen in the chair.

The minutes of the Twenty-sixth Annual Meeting were approved as printed.

The Symposium was introduced by Jerome Strauss, who stated that the Symposium was being held as a result of a number of discussions that had taken place in several standing committees of the Society concerning the desirability of the standardization of so-called "stainless steels" and certain of the non-ferrous alloys. It was felt that the time was not ripe for standardization, but that a useful purpose would be served by collecting data upon the properties of these alloys. A committee under the chairmanship of Mr. Strauss, appointed to act in an advisory capacity to the Committee on Papers and Publications, had arranged for the presentation of papers in the form of a Symposium, and considerable data, secured from manufacturers of various alloys, concerning their chemical composition and physical constants, were presented in summarized form.

The subject of corrosion-resistant alloys was covered in six papers as follows:

"Corrosion-Resistant Alloys—Past, Present and Future," by P. A. E. Armstrong, presented by the author.

"Corrosion-Resistant Alloys for Use in Acid Mine Water," by R. J. Anderson and G. M. Enos, which, in the absence of the authors, was read by title;

"Endurance Properties of Corrosion-Resistant Steels," by D. J. McAdam, Jr., presented by the author;

"Non-Rusting Chromium-Nickel Steels," by B. Strauss, presented in the absence of the author by P. D. Merica;

"Stainless Steels: Their Heat Treatment and Resistance to Sea-Water Corrosion," by Jerome Strauss and J. W. Talley, presented by Jerome Strauss;

"The Carrying Capacity of Ball Bearings Made of Stainless Steel," by Axel Hultgren, presented by Haakon Styri.

The presentation of these papers was followed by the presentation of discussion that had been submitted in written form on corrosion-resistant alloys by: W. B. Price, Jesse L. Jones, C. M. Johnson, B. D. Saklatwalla, R. E. Hall.

The session was then thrown open for oral discussion, which was participated in by: T. H. Nelson, J. A. Mathews, H. J. French, W. W. Waddington, Jerome Strauss.

The meeting then adjourned till 8 P. M., the Symposium being continued in the third session.[1]

SECOND SESSION—TUESDAY, JUNE 24, 3 P. M.

On Coal, Timber, Rubber and Textiles

(Held simultaneously with the First Session)

Vice-President F. M. Farmer in the chair.

The report of Committee D-5 on Coal and Coke was, in the absence of the chairman, A. C. Fieldner, presented by the vice-chairman, H. C. Porter. Minor editorial revisions in the Standard Specifications for Foundry Coke (D 17 – 16) were accepted as recommended by the committee. Revisions in the Standard Methods of Laboratory Sampling and Analysis of Coal (D 22 – 21) and of the Standard Methods of Laboratory Sampling and Analysis of Coke (D 37 – 21) which had been published as tentative in the Proceedings, were, on recommendation of the committee, referred to letter ballot of the Society for adoption as standard.

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[1] See page 15.

The Tentative Method of Test for Volume of Cell Space of Lump Coke (D 167 – 23 T) and the Tentative Specifications for Gas and Coking Coals (D 166 – 23 T) were referred to letter ballot for adoption as standard.

The proposed revised Tentative Definitions of Terms Relating to Coke (D 121 – 24 T) submitted by the committee were accepted for publication as tentative as a substitute for the present Tentative Definitions of Terms Relating to Coke.

The proposed revisions of the Tentative Definitions of Terms Relating to Coal (D 142 – 22 T) were accepted.

The proposed Tentative Method of Test for Fineness of Powdered Coal was accepted for publication as tentative.

On motion, the report was adopted.

A paper entitled "Structural Timbers: Defects and Their Influence on Strength," by J. A. Newlin and R. P. A. Johnson, was presented by Mr. Newlin.

The report of Committee D-7 on Timber was presented by the chairman, Hermann von Schrenk.

The proposed Tentative Methods of Chemical Analysis of Zinc Chloride were accepted for publication as tentative. The chairman then called on S. R. Church to present the report of Sub-Committee VI on Timber Preservatives. Mr. Church called attention to the work which the sub-committee had been carrying on in cooperation with other standing committees through Committee E-1, and referred particularly to a method of test for the determination of water which had been prepared by a sub-committee of Committee E-1. He recommended that a reference be inserted in the Standard Methods of Sampling and Analysis of Cresote Oil (D 38 – 18) to the new method of determination of water as a method for the determination of water *per se* in creosote oil. This was accepted as a revision of the report of Committee D-7.

On motion, this revision and the revisions appearing in the report of Committee D-7 of the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 18) were referred to letter ballot for adoption as standard.

The revisions of the Tentative Methods of Testing Small Clear Specimens of Timber (D 143 – 22 T) were accepted, the methods as revised being continued as tentative.

The proposed Tentative Methods for Conducting Static Tests of Timber in Structural Sizes were accepted for publication as tentative.

On motion, the report as amended was adopted.

The report of Committee D-7 was discussed jointly with the paper by J. A. Newlin and R. P. A. Johnson.

The report of Committee D-10 on Shipping Containers was presented by the chairman, J. A. Newlin, and after discussion, on motion was accepted as a report of progress.

The report of Committee D-11 on Rubber Products was presented by H. S. Vassar. The proposed revised Tentative Specifications for Steam Hose (D 54 – 24 T) submitted by the committee were accepted for publication as tentative, to replace the present Tentative Specifications for Steam Hose.

The following tentative standards were referred to letter ballot for adoption as standard without change:

Tentative Specifications for:

Adhesive Tape for General Use for Electrical Purposes (D 69 – 22 T),
Wrapped Air Hose for Use with Pneumatic Tools (D 46 – 23 T),
Rubber Belting for Power Transmission (D 53 – 23 T),
Wrapped Cold Water Hose (D 177 – 23 T),
Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 – 23 T).

The Tentative Methods of Testing Rubber Products (D 15 – 23 T) were referred to letter ballot of the Society for adoption to replace the present Standard Methods of Testing Cotton Rubber-Lined Hose (D 15 – 15).

The Tentative Specifications for Braided Air Hose for Use with Pneumatic Tools (D 60 – 23 T) were referred to letter ballot for adoption as standard, amended as indicated in the report.

On motion, the report was adopted.

The report of Committee D-13 on Textile Materials was presented by the chairman, A. E. Jury. The revisions of the Standard General Methods of Testing Cotton Fabrics (D 39 – 20), which had been submitted by the committee in 1923 and published as tentative in the Proceedings were referred to letter ballot for adoption as standard.

The revisions of the Tentative Specifications for Tolerances and Test Methods for Cotton Yarns and Cords (D 180 – 23 T) and the Tentative Specifications for Tolerances for Hose Ducks and Belt Ducks (D 181 – 23 T) were accepted, the specifications as revised being continued as tentative.

The proposed Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns, the proposed Tentative Specifications for Tolerances and Test Methods for Cotton Sewing Threads, and the proposed Tentative Specifications and Methods of Test for Osnaburg Cement Sacks were accepted for publication as tentative.

On motion, the report was adopted.

The meeting then adjourned till 8 P. M.

THIRD SESSION—TUESDAY, JUNE 24, 8 P. M.

Symposium on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys (Continued from First Session)

(Held simultaneously with the Fourth Session)

Past-President George K. Burgess in the chair.

This session consisted of a continuation of the Symposium which had been opened in the first session with a discussion of corrosion-resistant alloys. The second section of the Symposium consisted of a discussion on heat-resistant and electrical-resistance alloys, and was opened by the presentation of the following papers:

"Principles Underlying the Successful Use of Metals at High-Temperatures," by F. A. Fahrenwald, presented by the author.

"Deterioration of Some Metals in Hot, Reducing Ammonia Gases," by J. S. Vanick, presented by the author.

"Some Engineering Applications of High-Chromium Iron Alloys," by C. E. MacQuigg, presented by the author.

"Characteristics of Materials for Valves Operating at High-Temperatures," by J. B. Johnson and S. A. Christiansen, presented by Mr. Johnson.

"Some Electrical Properties of High-Resistance Alloys," by M. A. Hunter and A. Jones, presented by Mr. Hunter.

"Characteristics of Some Materials for Base-Metal Thermocouples," by F. E. Bash, presented by the author.

Discussions submitted in written form were presented by: W. S. Graham, F. R. Angell (read by Mr. Little).

The subject was then open for general discussion and the following participated: C. S. Gillette, P. A. E. Armstrong, W. H. Bassett, H. J. French, H. C. Knerr, F. A. Fahrenwald.

The meeting then adjourned till the following morning.

FOURTH SESSION—TUESDAY, JUNE 24, 8 P. M.

On Paints and Petroleum Products, Insulating Materials and Thermometers

(Held simultaneously with the Third Session)

J. H. Gibboney in the chair.

The report of Committee D-1 on Preservative Coatings for Structural Materials was presented, in the absence of the chairman, Allen Rogers, by the vice-chairman, H. A. Gardner. On the recommendation of the committee, the Tentative Method of Test for Specific Gravity of Pigments (D 153 - 23 T), the Tentative Methods of Testing Oleo-Resinous Varnishes (D 154-23 T) and the Tentative Specifications for Turpentine (D 13 - 21 T) were referred to letter ballot for adoption as standard. The Tentative Methods of Testing Shellac (D 29 - 23 T), amended as indicated in the report of the committee, were referred to letter ballot for adoption as standard to supersede the present Standard Methods of Testing Shellac (D 29 - 17). On recommendation of the committee the following specifications for pigments amended as indicated in the report were referred to letter ballot for adoption as standard.

Tentative Specifications for:

Zinc Oxide (D 79 - 21 T),
Leaded Zinc Oxide (D 80 - 21 T),
Basic Carbonate White Lead (D 81 - 21 T),
Basic Sulfate White Lead (D 82 - 21 T),
Red Lead (D 83 - 21 T),
Ocher (D 85 - 21 T).

The revisions of the Tentative Specifications for Iron Oxide and Iron Hydroxide (D 84 - 21 T) recommended by the committee were accepted and the specifications continued as tentative. The proposed Tentative Method of Test for the Determination of Wax in Shellac was accepted for publication as tentative, to be added when adopted as standard to the Methods of Testing Shellac.

Additional methods of testing varnish covering flash point, viscosity, and a water test were accepted for publication as tentative to be added, when adopted as standard, to the present Methods of Testing Oleo-Resinous Varnishes. The revision of the Standard Definitions of Terms Relating to Paint Specifications consisting of the withdrawal of the terms "bulk," and "voids," and a rewording of the definition for the term "fineness," were referred to letter ballot for approval.

The committee made a further recommendation not appearing in the report as preprinted to the effect that the Standard Specifications for Purity of Raw Tung Oil (D 12 - 16) be withdrawn so that there will be only one specification covering this product, namely, the Tentative Specifications for Raw Tung Oil (D 12 - 23 T). This recommendation was approved.

The proposed Tentative Method of Test for Coarse Particles in Paint Pigments and the Tentative Methods of Routine Analysis of Titanium Pigments, submitted by the committee, were accepted for publication as tentative.

On motion, the report of the committee as amended was adopted.

A paper entitled "Further Study of Accelerated Weathering: Effect of Variations in Exposure Cycle Combinations on Common Types of Varnishes," by H. A. Nelson and F. C. Schmutz, was presented by Mr. Nelson and discussed.

The report of Committee D-15 on Thermometers was presented by the chairman, W. H. Fulweiler. This report submitted nine proposed specifications for thermometers as follows:

Proposed Specifications for:

- A.S.T.M. Thermometer for Cleveland Open Cup, 20 to 760° F.
- A.S.T.M. Pensky-Martens High Flash Test Thermometer, 90 to 370° C. or 200 to 700° F.
- A.S.T.M. Cloud and Pour Test Thermometer, -38 to $+50°$ C. or -36 to $+120°$ F.
- A.S.T.M. Pensky-Martens and Tag. Flash Test Thermometer, -5 to $+110°$ C. or $+20$ to $+230°$ F.
- A.S.T.M. Low-Softening-Point Thermometer, 0 to 90° C. or 30 to 180° F.
- A.S.T.M. High-Softening-Point Thermometer, 30 to 160° C. or 85 to 320° F.
- A.S.T.M. Low-Distillation Thermometer, 0 to 300° C. or 30 to 580° F.
- A.S.T.M. High-Distillation Thermometer, 0 to 400° C. or 30 to 760° F.
- A.S.T.M. Paraffin Melting Point Thermometer, 25 to 70° C. or 80 to 160° F.

These specifications are for the use of the several standing committees having jurisdiction over the methods of test in which the thermometers are specified. Recommendations concerning the incorporation of these specifications in the appropriate methods of test are given in connection with the presentation of the reports of these several standing committees.

The report of the committee was, on motion, adopted.

The report of Committee D-2 on Petroleum Products and Lubricants was presented by the chairman, C. P. Van Gundy. The Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 - 23 T) and the Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 23 T) both amended as indicated in the report, were, on recommendation of the committee, referred to letter ballot for adoption as standard, the recommendation in reference to Methods D 95 being concurred in by Committee D-4 on Road and Paving Materials, which committee has joint jurisdiction over this method of test.

The Tentative Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 - 21 T) was referred to letter ballot for adoption as standard, as recommended by the committee.

The revisions of the following tentative methods of test recommended by the committee were accepted, the methods being continued as tentative:

Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products (D 86 - 23 T),
Tentative Method of Test for Melting Point of Petrolatum (D 127 - 22 T),
Tentative Method of Analysis of Grease (D 128 - 22 T).

The suggested revisions of the Tentative Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 - 23 T) as given in the report of the committee were further amended by changing the requirement for the distance of the source of heat from the oil tube to provide for an immersion heater at a distance of $1\frac{1}{4}$ in. (3 cm.) and further revised by the addition of the following footnote to the specified room temperatures for conducting the test.

"NOTE.—These limits are necessary for extreme accuracy in standardization and referee tests, but for routine purposes the use of higher temperatures up to 100° F. (37.8° C.) will not ordinarily cause an error of more than 1 per cent."

An additional requirement was added to the table showing dimensions of apparatus to the effect that the section of overflow rim must show a straight line from the outside of rim at top, to the bottom of gallery. With these amendments the revisions were accepted and the methods were continued as tentative.

The committee made a further recommendation for a revision of a tentative method of test which did not appear in the report as preprinted. This recommended revision consists in the addition to the Tentative Method of Test for Sulfur in Naphthas and Illuminating Oils (D 90 – 21 T) of the following section on scope:

> "This method is intended to be applied to illuminating oils and petroleum naphthas. It is not applicable to mixtures containing carbon bisulfide."

The proposed Tentative Method of Test for Burning Quality of Kerosene Oils submitted by the committee was accepted for publication as tentative with the addition of the following note:

> "The equipment used in this test is selected to secure results in a reasonably short time and it should be understood that this does not indicate any preference as to the proper type for general household use."

The Standard Method of Test for Carbon Residue (Conradson Method) and the Standard Method of Test for Free Acid in Lubricants were, on recommendation of the committee, withdrawn from the Standard Methods of Testing Lubricants (D 47 – 21) for publication as separate tentative standards.

In addition to the acceptance of the Specifications for High-Distillation Thermometer as given in the report of the committee as a revision of the Tentative Methods of Test for Distillation (D 86 – 23 T) the committee approved the following specifications for thermometers as prepared by Committee D-15 for incorporation in the appropriate methods of test.

Thermometer for Use in Test for Melting Point of Paraffin Wax (D 87 – 22),
Thermometer for Use in Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T),
Thermometer for Use in Test for Flash Point by Means of the Pensky-Martens Closed Tester (D 93 – 22),
Thermometer for Use in Test for Cloud and Pour Points of Petroleum Products (D 97 – 23 T).

The report as amended, on motion, was adopted.

A paper entitled "An Oxidation Method for Measuring the Stability of Mineral Oils," by T. S. Sligh, Jr., was presented by the author. Discussion was deferred till after the presentation of the report of Committee D-9 on Electrical Insulating Materials and a paper by E. A. Snyder on the Sludging Tests for Transformer Oils.

The report of Committee D-9 on Electrical Insulating Materials was then presented by the chairman, F. M. Farmer. The proposed revisions of the Standard Methods of Testing Molded Insulating

Materials (D 48 – 22) as given in the report were, on recommendation of the committee, unanimously approved for reference to letter ballot for adoption as standard, the committee having requested that the usual requirement for publication as tentative be waived.

The Tentative Methods of Testing Transformer and Switch Oils (D 117 – 21 T) were, on recommendation of the committee, referred to letter ballot for adoption as standard.

The revisions of the following tentative methods of test recommended by the committee were accepted, the methods being continued as tentative:

Tentative Methods of Testing Insulating Varnishes (D 115 – 23 T),
Tentative Methods of Testing Electrical Porcelain (D 116 – 21 T).
Tentative Method of Test for Dielectric Strength of Sheet and Tape Insulating Materials Under Momentary Dielectric Stress (D 149 – 23 T),
Tentative Methods of Testing Cable Splicing and Pothead Compounds (D 176 – 23 T).

The proposed Tentative Methods of Testing Untreated Insulating Paper, submitted by the committee, were accepted for publication as tentative.

The report of the committee, on motion, was adopted.

A paper entitled "Sludging Tests for Transformer Oils: A Criticism of Various Test Methods and a Proposed New Method of Test," by E. A. Snyder, was presented by the author, and discussed jointly with the paper previously presented by T. S. Sligh, Jr., with the report of Committee D-9 on Electrical Insulating Materials.

The meeting adjourned till the following morning.

FIFTH SESSION, WEDNESDAY, JUNE 25, 9.30 A. M.

On Non-Ferrous Metals, Corrosion and Metallography

(Held simultaneously with the Sixth Session)

Past-President G. H. Clamer in the chair.

The report of Committee B-2 on Non-Ferrous Metals and Alloys was presented by the chairman, William Campbell. The proposed revisions of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (B 4 – 13) and of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (B 5 – 13) recommended by the committee were accepted for publication as tentative.

The proposed revisions of the Standard Specifications for Brass Pipe, Standard Sizes (B 43 – 23) and of the Standard Specifications for Copper Pipe, Standard Sizes (B 42 – 23) recommended by the committee, extending the scope of the specifications to cover extra strong pipe, were approved and referred to letter ballot for adoption as standard, the committee having asked for the necessary nine-tenths vote to have these revisions adopted as standard without their first being published as tentative.

The proposed Tentative Specifications for Manganese-Bronze Ingots for Sand Castings (B 7 – 24 T) were accepted for publication as tentative to replace the standard specifications of that title. The standard specifications were accordingly withdrawn.

The revisions of the Standard Specifications for Light Aluminum Casting Alloys (B 26 – 21) recommended by the committee were accepted for publication as tentative.

The tentative revisions of the Standard Methods of Chemical Analysis of Pig Lead (B 35 – 20), which had been published as tentative since 1923, were referred to letter ballot for advancement to standard.

The Tentative Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 23 T) corrected as indicated in the report, were referred to letter ballot for advancement to standard. This recommendation had not been submitted to letter ballot in Committee B-2, and the action taken at the meeting is accordingly subject to such letter ballot, which is still to be reported.[1]

The following proposed tentative specifications submitted by the committee were accepted for publication as tentative:

Proposed Tentative Specifications for:

Seamless Muntz Metal Condenser Tubes and Ferrule Stock,
73–30 Brass Condenser Tubes and Ferrule Stock,
Manganese-Bronze Sand Castings,
Phosphor Copper,
Phosphor Tin,
Silicon Copper.

The recommendation to revise the appendix of the Tentative Specifications for White Metal Bearing Alloys (B 23 – 18 T) was approved.

The appendix to the report, entitled "The Effect of Impurities on the Compressive Strength and Brinell Hardness of Babbitt Metal at Normal and Elevated Temperatures," by J. R. Freeman, Jr., and P. F. Brandt, was presented and discussed.

The report of the committee as amended was, on motion, adopted.

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[1] The letter ballot vote in Committee B–2 on this recommendation resulted as follows: Affirmative, 25; Negative, 3; Not voting, 18.

The report of Committee A-5 on Corrosion of Iron and Steel was presented by the chairman, J. H. Gibboney. The proposed Tentative Specifications for Hot-Dipped Galvanized Sheets submitted by the committee were accepted for publication as tentative.

The Tentative Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 – 23 T) and the Tentative Methods of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets (A 91 – 23 T) were, on recommendation of the committee, referred to letter ballot for adoption as standard.

The report of the committee was, on motion, adopted.

A paper entitled "Types of Apparatus Used in Testing the Corrodibility of Metals," by H. S. Rawdon, A. I. Krynitsky and W. H. Finkeldey, was presented by Mr. Rawdon. The discussion of this paper was deferred until after the presentation of the report of Committee B-3 and the paper entitled "An Accelerated Electrolytic Corrosion Test," by R. J. Anderson and G. M. Enos.

The report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys was presented by the chairman, E. C. Lathrop.

The report was, on motion, accepted as a report of progress.

A paper entitled "An Accelerated Electrolytic Corrosion Test," by R. J. Anderson and G. M. Enos, was, in the absence of the authors, read by title.

The subject of corrosion testing was then opened for discussion.

The report of Committee E-4 on Metallography was presented by the chairman, W. H. Bassett. The Tentative Definitions of Terms Relating to Metallography (E 2 – 23 T) were, on recommendation of the committee, accepted for reference to letter ballot for adoption as standard in their revised form as given in the report.

The Tentative Recommended Practice for Photography as Applied to Metallography (E 7 – 22 T) was referred to letter ballot for adoption as standard to be combined with the Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys (E 2 – 20).

The Tentative Methods of Metallographic Testing of Iron and Steel (E 3 – 23 T) and the Tentative Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 23 T) were referred to letter ballot for adoption as standard.

The report of the committee was, on motion, adopted.

The meeting then adjourned till 8.30 P. M.

SIXTH SESSION—WEDNESDAY, JUNE 25, 9.30 A. M.

On Gypsum Products and Ceramics

(Held simultaneously with the Fifth Session)

A. T. Goldbeck in the chair.

The report of Committee C-3 on Brick was presented by the chairman, T. R. Lawson. The recommended sizes for paving brick as given in the report of the committee, agreeing with the recommendations of the Division of Simplified Practice, were accepted for publication as an appendix to the Standard Specifications for Paving Brick (C 7 - 15).

The proposed Tentative Specifications for Concrete Building Brick submitted by the committee were accepted for publication as tentative.

The rewordings of the definitions for "surface clay," "fire clay," and "shale" appearing in the Standard Specifications for Sewer Brick (C 32-23), to agree with the definitions prepared by Committee E-8 on Nomenclature and Definitions, were approved, for reference to letter ballot for adoption as standard.

The report of the committee was, on motion, adopted.

The report of Committee C-4 on Clay and Cement-Concrete Sewer Pipe was presented by the chairman, A. J. Provost, Jr. The tentative revisions of the Standard Specifications for Clay Sewer Pipe (C 13 - 20) and of the Standard Specifications for Cement-Concrete Sewer Pipe (C 14 - 20) as submitted by the committee in 1923 were referred to letter ballot for adoption as standard.

The proposed revision of the Standard Specifications for Cement-Concrete Sewer Pipe (C 14 - 20), as given in the report, was accepted for publication as tentative.

The definitions for the terms "surface clay," "fire clay" and "shale" prepared by Committee E-8 were on recommendation of Committee C-4 approved to replace the definitions for these terms appearing in the standards under the jurisdiction of this committee.

The report of the committee was, on motion, adopted.

The report of Committee C-7 on Lime was presented by the secretary, R. P. Brown. The proposed revised Tentative Specifications for Quicklime for Structural Purposes (C 5 - 24 T) were accepted for publication as tentative as a substitute for the specifications of the same title submitted in 1922.

The proposed revisions of the Tentative Specifications for Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper (C 45 - 22 T), the Tentative Specifications for Quicklime and Hydrated Lime for Use in the Manufacture of

Sulfite Pulp (C 46 - 22 T) and of the Tentative Definitions of Terms Relating to Lime (C 51 - 22 T) were accepted, the specifications and the definitions of terms being continued as tentative.

The proposed revised Tentative Methods for Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (C 50 - 24 T) were accepted for publication as tentative as a substitute for the methods of the same title presented in 1923.

The Tentative Specifications for Hydrated Lime for Structural Purposes (C 6 - 23 T), the Tentative Specifications for Quicklime and Hydrated Lime for Use in the Textile Industry (C 48 - 22 T) and for Quicklime and Hydrated Lime for the Manufacture of Silica Brick (C 49 - 22 T) were, on recommendation of the committee, referred to letter ballot for adoption as standard.

The committee then submitted proposed Tentative Specifications for Quicklime for Use in Water Treatment and for Hydrated Lime for Use in Water Treatment. The first of these two specifications as submitted by the committee contained a note reading as follows:

"NOTE.—Since the efficacy of lime for use in water treatment is dependent upon the available lime content, some contracts for the purchase of lime for this purpose include a basis for adjustment for variations of the available lime content from the established standard. Investigation has shown that the variation in utility is approximately in the ratio of 1.5 per cent for each 1 per cent variation from the 90-per-cent standard and an adjustment on this basis appears to be the most equitable."

The second of these specifications contained a similar note. After some discussion on the advisability of including a note of this character and further of the desirability of having some explanation of such a note, either as an amplification of the note or in the report of the committee, the motion to accept these specifications for publication as tentative was amended to withdraw the note from the specifications for further consideration by the committee. The standards as thus amended were accepted for publication as tentative.

The report of the committee as amended was, on motion, adopted.

An informal report of Committee C-5 on Fireproofing was presented by the chairman, Ira H. Woolson, outlining the activities of the committee in connection with a newly organized Sectional Committee of the American Engineering Standards Committee, which had been reviewing the specifications for fire tests prepared by Committee C-5.

The report of the committee was, on motion, accepted as a report of progress.

The report of Committee C-11 on Gypsum was presented by the chairman, W. E. Emley. The revision of the Standard Specifications for Calcined Gypsum (C 23 – 22) consisting in the removal of an editorial note, was approved.

The revisions of the Tentative Specifications for Gypsum (C 22 – 23 T) and of the Tentative Specifications for Gypsum Plastering Sand (C 35 – 21 T) were accepted, the specifications being continued as tentative.

The report of the committee stated that revisions were in contemplation in the Tentative Specifications for Gypsum Wall Board (C 36 – 22 T). These revisions were presented at the meeting and consisted in changing Section 4 (*c*) from its present form: namely,

> "The lengths shall be 4 ft. (1.22 meter), 5 ft. (1.52 meter), 6 ft. (1.83 meter), 7 ft. (2.13 meter), 8 ft. (2.44 meter), or 10 ft. (3.04 meter), except that a variation of ±⅜ in. (9.5 mm.) from these lengths is permissible."

to read as follows:

> "The lengths shall be from 4 ft. (1.22 meter) to 12 ft. (3.66 meter) inclusive, except that a tolerance of ⅜ in. (9.5 mm.) from the length of individual boards is permissible. Special boards may be cut to any desired length within the limits prescribed."

These revisions were accepted, the specifications being continued as tentative.

The proposed revised Tentative Specifications for Gypsum Partition Tile or Block (C 52 – 24 T) submitted by the committee were accepted for publication as tentative as a substitute for tentative specifications of the same title submitted in 1923.

Revised Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 24 T) were presented as a substitute for definitions of the same title published in 1923. Objection was raised to the definitions for the terms "gypsum plaster board" and "gypsum wall board" in that these definitions described plaster board and wall board as "incombustible." It was felt that the word "incombustible" should be reserved for truly incombustible boards, whereas gypsum plaster board and gypsum wall board are in part made up of combustible material. On motion, it was voted to withdraw the definitions of the terms "gypsum plaster board" and "gypsum wall board" and to refer these back to the committee for further consideration, these two definitions reading as follows:

> "*Gypsum Plaster Board.*—An incombustible sheet composed chiefly of gypsum, designed to be used as a lath for the reception of gypsum plaster.
>
> "*Gypsum Wall Board.*—An incombustible sheet composed chiefly of gypsum bonded to fibrous surfacing material and designed to be used, without the addition of plaster, for walls, ceilings, or partitions and affording a surface suitable to receive decoration."

The tentative definitions of terms with the exception of these two definitions were accepted for publication as tentative.

The report of the committee as amended was, on motion, adopted.

A paper entitled "Properties of Gypsum Tile," by J. M. Porter, was presented by the author and discussed.

The report of Committee C-10 on Hollow Building Tile was presented by the chairman, S. H. Ingberg.

The Tentative Definitions of Terms Relating to Hollow Tile (C 43 – 23 T) revised as recommended by the committee, were referred to letter ballot for adoption as standard.

The proposed Tentative Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 24 T) were accepted for publication as tentative as a substitute for the Tentative Specifications for Clay Hollow Building Tile (C 34 – 21 T).

The proposed Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile were accepted for publication as tentative as submitted by the committee.

The proposed Tentative Specifications and Tests for Hollow Burned-Clay Floor Tile submitted by the committee were accepted for publication as tentative with the following revisions approved by the committee:

Section 5.—Change the first sentence to read as follows by the omission of the words in brackets:

> "The tile shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C 19) of the American Society for Testing Materials, as they apply to hollow floor tile, and to be acceptable shall develop the safe resistance period specified in the contract. [and in all cases shall give a resistance not less than that equivalent to the requirements for the one-hour classification where the fire resistance of the construction is limited by the properties of the tile.]"

Section 13.—Change this section to read as follows by the addition of the italicized words:

> "For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. *Where tile of several designs are used, enough samples shall be weighed to determine the true average weight in pounds per square foot for the construction.* In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. Samples for the freezing tests shall be taken from tile that have not been subjected to strength or fire tests."

Section 22.—Change from its present form: namely,

> "All tile shall be tested in the position in which they are designed to be used."

to read as follows:

> "In the tests the tile shall be loaded in the direction in which they receive the principal stress in the structure."

The report of the committee as amended was, on motion, adopted.

A paper was presented by S. H. Ingberg covering data on compression tests of brick masonry and discussed.

The meeting adjourned till 8.30 P. M.

SEVENTH SESSION—WEDNESDAY, JUNE 25, 8.30 P. M.

Presidential Address and Reports of Administrative Committees

Past-President A. A. Stevenson in the chair.

The chairman introduced President Guilliaem Aertsen who presented the annual Presidential Address.

The Secretary-Treasurer presented the annual report of the Executive Committee, discussing membership activities, the work of standing committees, publications, finances, and administrative matters relating to committee activities and relations with other Societies. Special attention was called to the organization of a Committee on Correlation of Research in the A.S.T.M., the formation of which had been discussed at the previous annual meeting.

On motion the report of the Executive Committee was adopted.

The report of Committee E-6 on Papers and Publications was presented by the chairman, C. L. Warwick, and adopted.

The report of the committee of tellers consisting of F. Zeleny and J. H. Hall appointed to canvass the letter ballot on election of officers was received. The tellers reported that 885 legal ballots had been cast, and in accordance therewith the Chair announced the election of the following officers:

For President, to serve for one year: F. M. Farmer;
For Vice-President, to serve for two years: J. H. Gibboney;
For members of Executive Committee, to serve for two years: William Campbell, A. E. Jury, Anson Marston, John A. Mathews.

The Chairman requested Past-Presidents George S. Webster and George K. Burgess to escort the President-Elect to the chair. Mr. Farmer expressed his appreciation of the honor of election as President and pledged himself to maintain the traditions of the Society, to promote its interests and to do his best to increase its usefulness to the members and to the industry.

The Vice-President-Elect, J. H. Gibboney, was then escorted to the chair by Past-Presidents J. A. Capp and G. H. Clamer. Mr.

Gibboney expressed his appreciation of his election as Vice-President and the desire to be of service in advancing the welfare of the Society.

The meeting then adjourned till the following morning and was followed by an informal dance and smoker.

EIGHTH SESSION—THURSDAY, JUNE 26, 9.30 A. M.

On Steel

(Held simultaneously with the Ninth Session)

President Guilliaem Aertsen in the chair.

The report of Committee A-1 on Steel was presented by its chairman, F. M. Waring. Before taking up the detailed recommendations in the printed report, Mr. Waring stated that at a meeting of Committee A-1 held the preceding day the committee had voted to approve the recommendations that were being made at this annual meeting by Committee A-2 on Wrought Iron respecting revisions in the Tentative Specifications for Iron and Steel Chain (A 56 – 21 T) and the recommendations of Committee A-4 on Heat Treatment of Iron and Steel concerning the Recommended Practice for Heat Treatment of Steel Castings (A 36 – 22 T). He also stated that the committee at its meeting the preceding day voted to withdraw from its report the proposed Tentative Methods of Sampling Finished Steel Material for Check Analysis and that all references thereto in the report are to be omitted. Attention was also called to the correction of an error in giving proposed revisions in the Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 21), item No. 15 in the appendix to the report. The committee is recommending that Table I of these specifications be modified to include hydrostatic pressures for seamless pipe, and a necessary revision in Section 5 of the specifications was inadvertently omitted from the report. The committee recommended that this section be modified by omitting Paragraph (*b*) and changing Paragraph (*a*) to read:

> "Pipe shall be tested at the mill to the hydrostatic pressures specified in Table I."

The consent of the meeting was given to the committee to make these changes in its printed report.

Mr. Waring then proceeded to present the recommendations of the committee as printed in its report. The meeting consented to consider *en bloc* the proposed revisions in standards listed under Group A in the report, as follows:

(*a*) *Revisions Recommended for Adoption as Presented in 1922 and 1923, without amendment:*

For Steel Track Spikes (A 65 – 18).
For Boiler and Firebox Steel for Locomotives (A 30 – 21).

(*b*) *Revisions Recommended for Adoption as Presented in 1922 and 1923, and amended in 1924 as indicated in the Appendix:*

For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 21).
For Welded and Seamless Steel Pipe (A 53 – 21).
For Automobile Carbon and Alloy Steels (A 29 – 21).
For Open-Hearth Steel Girder and High Tee Rails (A 2 – 21).
For Structural Nickel Steel (A 8 – 21).
For Structural Steel for Locomotives (A 10 – 21).
For Structural Steel for Cars (A 11 – 21).
For Steel Castings (A 27 – 21).
For Boiler Rivet Steel (A 31 – 21).
Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 14)
Methods of Chemical Analysis of Alloy Steels (A 55 – 15).

Mr. Waring moved that these revisions be approved and referred to letter ballot for adoption as standard. This motion received an affirmative majority vote with some negative votes cast. The Secretary suggested since negative votes had been cast on this motion it was desirable to ascertain against which specifications they were directed and accordingly suggested the action be reconsidered and the specifications put to vote separately. A motion to rescind the previous action was passed and the specifications were voted upon separately. All of the proposed revisions in these specifications were acted upon unanimously, with the exception of revisions in the following three specifications, which were approved for reference to letter ballot with some negative votes:

For Structural Nickel Steel (A 8 – 21).
For Structural Steel for Locomotives (A 10 – 21).
For Structural Steel for Cars (A 11 – 21).

Mr. Waring then presented proposed revisions in specifications listed in Group B in the report, these revisions being proposed for the first time and therefore requiring a nine-tenths vote of those voting for reference to a letter ballot vote of the Society. On separate motion, revisions in the following three specifications were referred to letter ballot of the Society:

For Carbon-Steel Rails (A 1 – 21).
For Low-Carbon-Steel Splice Bars (A 3 – 14).
For Quenched Carbon-Steel Track Bolts (A 50 – 21).

A motion to refer proposed revisions in the Standard Specifications for Structural Steel for Bridges (A 7 – 21) to letter ballot for adoption as standard received a vote of 24 affirmative, 6 negative. Since the number of affirmative votes was less than the necessary nine-tenths, the Chair declared the motion lost. A. W. Carpenter, chairman of Sub-Committee II on Structural Steel for Bridges, Buildings and Rolling Stock, of Committee A-1, explained that the revisions that had been voted on were the result of agreement with the American Railway Engineering Association in joint conference in order to bring about exact concordance between the specifications of the two bodies for structural steel for bridges and expressed his regret that the results of such cooperative work should be entirely lost without there being further opportunity to consider such objections to the revisions as existed. A. A. Stevenson moved to rescind the previous action. This motion was carried and the chair declared the action rescinded. Discussion of the subject then developed that those voting in the negative on these revisions objected only to the following note which it was proposed to add to Table II of these Specifications on "Permissible Overweights of Plates Ordered to Thickness":

> "NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

Mr. Waring then moved that all of the proposed revisions in these specifications except the proposed note to Table II be approved and referred to letter ballot for adoption as standard. This motion was seconded and unanimously carried. Mr. Waring then moved that the proposed note to Table II be approved and referred to letter ballot. After considerable discussion this motion was put to vote, resulting in 95 affirmative and 13 negative votes. Since the number of affirmative votes was less than the required nine-tenths, the Chair declared the motion lost.

Mr. Waring then moved that the proposed revisions in the Specifications for Structural Steel for Buildings (A 9 – 21) be referred to letter ballot for adoption as standard. H. J. Force moved to amend this motion to the effect that the vote previously announced, 95 affirmative and 13 negative, shall apply to the proposed revision of Table II of these specifications, which is the same as in the preceding specifications. This amendment was lost. Mr. Waring then offered a substitute motion, that all of the proposed revisions in the Standard Specifications for Structural Steel for Buildings recommended by the committee, except the proposed note to Table II of the specifications, be referred to letter ballot of the Society. This motion was unanimously carried. Mr. Waring then moved that the proposed note be referred to letter ballot of the Society. An amendment to this motion that the note be referred back to the committee for clarification was defeated. The original motion was then put to vote, resulting in 65 affirmative and 18 negative votes. Since 75 affirmative votes would have been required to pass the motion, the Chair declared the motion lost.

A. A. Stevenson having pointed out that proposed revisions in three specifications previously acted upon in the affirmative contained the same proposed footnote to the table of permissible overweights of plates ordered to thickness, namely, Specifications for Structural Nickel Steel (A 8 – 21), for Structural Steel for Locomotives (A 10 – 21) and for Structural Steel for Cars (A 11 – 21), J. J. Shuman moved that the action taken with reference to this footnote in these three specifications be reconsidered. This motion was seconded and unanimously carried. H. J. Force moved that this note as applied to the three specifications be referred back to Committee A-1 for further consideration, and this motion was unanimously adopted.

Mr. Waring then moved that the proposed revisions in the Specifications for Rivet Steel for Ships (A 13 – 21) be referred to letter ballot for adoption as standard. This motion was carried with one negative vote.

Mr. Waring then moved that the proposed revisions in the following specifications be referred to letter ballot for adoption as standard:

For Wrought Solid Carbon-Steel Wheels for Steam Railway Service (A 57 – 23).
For Wrought Carbon-Steel Wheels for Electric Railway Service (A 25 – 23).
For Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service (A 52 – 18).
For Cold-Drawn Bessemer Steel Automatic Screw Stock (A 32 – 14).
For Cold-Drawn Open-Hearth Steel Automatic Screw Stock (A 54 – 15).
For Commercial Bar Steels (A 80 – 21).

This motion was unanimously carried.

Mr. Waring then moved that the proposed revisions in the following tentative standards, as printed in the committee's report, be approved and that the specifications as thus amended be advanced to standard:

For Steel Castings (A 27 – 23 T).

For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 22 T).

For Boiler and Firebox Steel for Stationary Service (A 70 – 23 T).

Methods of Chemical Analysis of Plain Carbon Steels (A 33 – 22 T).

Methods of Chemical Analysis of Alloy Steels (A 55 – 22 T).

This motion was unanimously carried.

The proposed revisions in the Tentative Specifications for Carbon Tool Steel (A 71 – 21 T) were accepted as printed in the committee's report. The proposed new Tentative Specifications for High-Speed Tool Steel, as appended to the committee's report, were also accepted for publication as tentative.

Mr. Waring then moved that the committee's report as amended be accepted as a whole for publication in the Proceedings, and this motion was unanimously carried.

The report of Committee A-4 on Heat Treatment of Iron and Steel, in the absence of the chairman, H. M. Boylston, was presented by the secretary, J. H. Hall. The revisions of the Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects (A 35 – 21) recommended by the committee were referred to letter ballot for adoption. These revisions were presented for the first time without having been published as tentative, but unanimous vote was received on their acceptance.

The Tentative Recommended Practice for Heat Treatment of Carbon-Steel Castings (A 36 – 22 T) as revised by the committee was referred to letter ballot for adoption to supersede the present Recommended Practice for Annealing of Carbon-Steel Castings (A 36 – 14).

The report of the committee was, on motion, adopted.

The report of the Joint Committee on Investigation of Phosphorus and Sulfur in Steel was presented by the chairman, George K. Burgess. The report was submitted in three sections, namely:

Third Preliminary Report: Effect of Sulfur on Endurance Properties of Rivet Steel;

Fourth Preliminary Report: Metallographic Investigation of Effect of Sulfur on Rivet Steel;

Fifth Preliminary Report: Effect of Sulfur on Structural Steel.

The chairman called on D. J. McAdam, Jr., and C. L. Warwick to present certain portions of the report.

A paper entitled "How Shall the Benefits of A.S.T.M. Standardization be Secured to the Small User?" by T. H. Wiggin, was presented by the author and discussed. At the conclusion of the discussion, action was taken to refer the question of promoting the use of A.S.T.M. specifications among small users of material to the Executive Committee.

A paper entitled "High Tensile Strengths with Low-Carbon Steels," by R. H. Smith, was presented by the author.

The report of Committee A-9 on Ferro Alloys in the absence of the chairman, F. C. Langenberg, was presented by the secretary, Charles McKnight, Jr., and adopted.

A paper entitled "Composition and Physical Properties of Cast 12-per-cent Manganese Steel," by J. H. Hall and G. R. Hanks, was presented by Mr. Hall.

The meeting adjourned till 8.30 P. M.

NINTH SESSION—WEDNESDAY, JUNE 26, 9.30 A. M.

On Road and Paving Materials and Waterproofing

(Held Simultaneously with the Eighth Session)

Vice-President F. M. Farmer in the chair.

Papers entitled "Accelerated Wear Tests of Concrete Pavements," by F. H. Jackson and J. T. Pauls, and "Methods of Securing Samples of Completed Pavements, With Reference to the Determination of the Quality of the Cement-Concrete Foundation," by E. E. Butterfield, were presented by Mr. Jackson and Mr. Butterfield, respectively, and discussed.

The report of Committee D-4 on Road and Paving Materials was presented by the chairman, F. P. Smith. The proposed revisions of the Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (D 36 – 21) and the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 20) as recommended by the committee were referred to letter ballot for adoption as standard, the committee having asked for the necessary nine-tenths vote.

In this connection the committee amplified its report to recommend an insertion of the requirements of the specifications for softening point thermometers prepared by Committee D-15.

The proposed revisions of the Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 – 23) and of the Standard Specifications for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 – 23) recommended by the committee were accepted for publication as tentative.

The proposed revisions of the following Tentative Specifications were accepted, the specifications being continued as tentative:

Tentative Specifications for:

Asphalt Cement, 70 to 90 Penetration, for Use in Asphalt Macadam Pavements (D 102 – 23 T);
Asphalt Cement, 90 to 120 Penetration, for Use in Asphalt Macadam Pavements (D 103 – 23 T);
Broken Slag for Bituminous Macadam Wearing Course (D 159 – 23 T);
Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type) (D 160 – 23 T);
Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type) (D 161 – 23 T).

The proposed revisions of the Tentative Method of Float Test for Bituminous Road Materials (D 139 – 23 T) recommended by the committee were accepted, the methods being continued as tentative. Here again the committee amplified its report to include the recommendation that the Specifications for Low-Softening Point Thermometer prepared by Committee D-15 be inserted in the tentative methods.

The proposed revisions of the Tentative Method of Analysis of Subgrade Soils (D 137 – 23 T) were accepted, the methods being continued as tentative.

The following proposed tentative specifications submitted by the committee were accepted for publication as tentative:

Specifications for Broken Stone for Waterbound Base:
Specifications for Broken Stone for Waterbound Macadam Surface Course:
Specifications for Broken Stone for Bituminous Macadam;
Specifications for Broken Stone for Bituminous Concrete Base;
Specifications for Broken Stone for Bituminous Concrete Surface;
Specifications for Broken Slag for Bituminous Macadam Base;
Specifications for Broken Slag for Bituminous Concrete Base.

The committee endorsed the recommendation of Committee D-2 on Petroleum Products and Lubricants to advance to standard the Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T), this method of test being under the joint jurisdiction of the two committees.

On recommendation of the committee, the Standard Method of Test for Quantity of Clay and Silt in Sand for Highway Construction

(D 74 – 21) and the Standard Method of Test for Soluble Bitumen (D 4 – 11) were withdrawn from the Book of Standards, these two methods being superseded by the Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 22 T) and the Tentative Method of Test for the Determination of Bitumen (D 4 – 23 T), respectively.

The committee made the following recommendation not appearing in its report that the tentative revisions of the Standard Specifications for Materials for Cement Mortar Bed for Brick, Stone Block and Wood Block Pavements (D 58 – 20) and of the Standard Methods of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials (D 55 – 19) be advanced to standard. These recommendations were approved for reference to letter ballot for adoption as standard.

The committee further recommended that certain changes in form be made in the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 18) by the insertion of the specifications for High-Distillation Thermometer prepared by Committee D-15 and the insertion of an illustration of a flask to be used in connection with this test with a notation that dimensions shown thereon are outside dimensions.

The committee also requested permission to include the following statement as an addendum to its report:

> "The Sectional Committee on Distillation desires to give notice that it will recommend a revision of the present Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 18) next year.
>
> "The important points subject to revision are: First, the rate of distillation; second, the use of corrected or uncorrected thermometers; third, the method of handling the residue.
>
> "The section will also consider the possible substitution of a new type of flask that may be found acceptable to both Committees D-2 and D-7. The present dimensions of the D-4 flask are subject to misinterpretation, owing to the fact that the present description does not specify whether internal or external dimensions are indicated. The Sectional Committee recommends that Committee D-4 report that in the reprinting of the Method of Test D 20 in the 1924 Book of Standards the original sketch of the flask be reprinted and that the words 'external dimensions' be added to the list of dimensions."

The report of the committee as amended was, on motion, adopted.

A paper entitled "Blown Oils," by H. B. Pullar, was presented by the author and discussed.

The report of Committee D-8 on Waterproofing Materials was at the request of the chairman, S. T. Wagner, presented by the vice-chairman, C. N. Forrest. The proposed revisions of the following

Tentative Specifications recommended by the committee were accepted, the specifications being continued as tentative:

Tentative Specifications for:

Asphalt Mastic for Use in Waterproofing (D 169 - 23 T);
Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 - 23 T);
Bituminous Grout for Use in Waterproofing Below Ground Level (D 171 - 23 T);
Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level (D 40 - 23 T);
Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level (D 144 - 23 T);
High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (D 42 - 23 T);
High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level (D 145 - 23 T).

The revisions of the Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 - 23 T) recommended by the committee were accepted, the methods being continued as tentative.

The proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level and the proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level were accepted for publication as tentative as submitted by the committee.

The report of the committee was, on motion, adopted.

The meeting adjourned till 8 P. M.

TENTH SESSION—THURSDAY, JUNE 26, 8 P. M.

On Methods of Testing and Nomenclature

Vice-President W. H. Fulweiler in the chair.

The report of Committee E-8 on Nomenclature and Definitions was presented by the chairman, Cloyd M. Chapman. The proposed definition for the term "sand," was accepted for publication as tentative.

The proposed definitions for the terms "clay," "surface clay," "fire clay," "shale" and "clay separate" submitted by the committee were approved. Recommendations concerning the adoption of these definitions are made by the various standing committees having jurisdiction over the standards in which the definitions appear.

The suggested definitions for terms relating to specific gravity as appended to the report of the committee were discussed.

The report of the committee was, on motion, adopted.

The meeting passed a resolution expressing the appreciation of the Society for the work that has been accomplished by Committee E-8.

The report of Committee E-1 on Methods of Testing was presented by the chairman, J. A. Capp. Mr. Capp called on H. F. Moore and F. G. Breyer to present those portions of the report dealing with the activities of their respective sub-committees, namely, the Mechanical Testing of Metallic Materials and the Classification of Material According to Size.

The Tentative Methods of Verification of Testing Machines (E 4 - 23 T), revised as recommended by the committee, were referred to letter ballot for adoption as standard.

The proposed Tentative Methods of Tension Testing of Metallic Materials, the proposed Tentative Methods of Compression Testing of Metallic Materials and the proposed Tentative Methods of Brinell Hardness Testing of Metallic Materials, submitted by the committee, were accepted for publication as tentative.

The revised Tentative Definitions of Terms Relating to Methods of Testing (E 6 - 24 T) were accepted for publication as tentative to replace those of the same title published in 1923.

In view of the submission of these various tentative standards, the Standard Methods of Mechanical Testing of Metallic Materials (E 1 - 18) were withdrawn.

A Tentative Method of Verification of Testing Machines by Means of an Elastic Calibration Bar was accepted for publication as tentative to be added, when adopted, to the present Methods of Verification.

A Method of Determining Elastic Limit by Means of the Proof-Load Method was submitted as information as well as definitions for the terms "tension," "compression," "flexure," "torsion," and "shear."

A recommended series of testing sieves, together with requirements therefor, was accepted for publication in the report of the committee.

The report of the committee was, on motion, adopted.

Papers entitled "A Study of Sieve Specifications," by L. V. Judson, and "Influence of Diameter of Wire on Performance of Sieves," by D. A. Abrams, were presented by Mr. Judson and F. R. McMillan, respectively.

Papers entitled "Tension Tests of Thin-Gage Metals and Light

Alloys," by H. A. Anderson," and "Determination of Poisson's Ratio and a Suggestion for Its Use in Stress Analysis," by T. M. Jasper, were presented by the respective authors, and discussed.

A paper entitled "Direct Measurement of Poisson's Ratio for Concrete," by A. N. Johnson, was presented by the author.

The meeting adjourned till the following morning.

ELEVENTH SESSION—FRIDAY, JUNE 27, 9.30 A. M.

On Magnetic Analysis and Fatigue of Metals

(Held simultaneously with the Twelfth Session)

Past-President J. A. Capp in the chair.

The report of Committee A-6 on Magnetic Properties, in the absence of the chairman, C. W. Burrows, was presented by Thomas Spooner. The Tentative Methods of Test for Magnetic Properties of Iron and Steel (A 34 - 23 T) were referred to letter ballot for adoption as standard as a substitute for the present standard methods of the same title (A 34 - 18).

The report of the committee was, on motion, adopted.

The report of Committee A-8 on Magnetic Analysis was presented by the chairman, F. P. Fahy.

The report of the committee was, on motion, accepted as a report of progress.

A paper entitled "Magnetic Tests of A.S.T.M. Drills," by W. B. Kouwenhoven was presented by the author.

A paper entitled "Notes on Some Endurance Tests of Metals," by H. W. Gillett and E. L. Mack (presented by Mr. Gillett) and the two papers entitled "Accelerated Fatigue Tests and Notes on the Endurance Range of Steel," by D. J. McAdam, Jr., and "Resistance of Metals to Repeated Static and Impact Stresses," by R. R. Moore, presented by the respective authors, were discussed jointly, since these three papers all dealt with the subject of fatigue testing.

The meeting adjourned till 8 P. M.

TWELFTH SESSION—FRIDAY, JUNE 27, 9.30 A. M.

On Cement and Concrete

(Held simultaneously with the Eleventh Session)

Past-President George S. Webster in the chair.

The report of Committee C-1 on Cement was presented by the chairman, R. S. Greenman.

The report of the committee was, on motion, accepted as a report of progress.

A paper entitled "Laboratory Investigations of the Influence of Curing Conditions and Various Admixtures on the Life of Concrete Stored in Sulfate Solutions as Indicated by Physical Changes," by D. G. Miller, was presented by the author and discussed.

The report of Committee C-6 on Drain Tile, in the absence of the chairman, Anson Marston, was presented by S. H. McCrory. The tentative revisions of the Standard Specifications for Drain Tile (C 4 – 21) including revised wordings for the definitions of the terms "surface clay," "fire clay," and "shale," were referred to letter ballot for adoption as standard with slight changes in the definitions to make these conform to the definitions as prepared by Committee E-8.

The report of the committee was, on motion, adopted.

A paper entitled "Influence of Aggregates Upon Shrinkage of Mortar and Concrete," by Cloyd M. Chapman, was presented by the author and discussed.

A paper entitled "Effect of End Condition of Test Cylinder on the Reliability of Compression Tests of Concrete," by H. F. Gonnerman, was presented by F. R. McMillan and discussed.

A paper entitled "Effect of Finely Divided Lignite Coal on the Strength of Concrete," by I. F. Morrison and H. R. Webb, was presented by D. A. Abrams, and discussed.

THIRTEENTH SESSION—FRIDAY, JUNE 27, 8 P. M.

On Wrought and Cast Iron

(Held simultaneously with the Fourteenth Session)

Past-President C. D. Young in the chair.

The report of Committee A-2 on Wrought Iron was presented by the chairman, H. E. Smith. The proposed revisions of the Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 21) submitted by the committee were referred to letter ballot for adoption as standard, these revisions having been published in 1922.

The revisions in the Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 18) recommended by the committee, for the adoption of which the committee asked a nine-tenths vote, were referred to letter ballot for adoption as standard with a further revision in Section 9, making this section read as follows:

> "Unless otherwise specified one test shall be made from each lot of 10 blooms or less and from each lot of 4000 lb. or less of forgings. These tests shall be made on prolongations the full size of the blooms or the largest section of the forging, and for test purposes, prolongations shall be furnished on at least 20 per cent of the blooms or forgings. In the case of small forgings, one

forging may be used for test purposes, in which case one test will represent not more than 100 forgings."

The proposed revisions of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 21) the adoption of which required a nine-tenths vote was referred to letter ballot for adoption as standard as recommended by the committee.

The revised Tentative Specifications for Iron and Steel Chain (A 56 – 23 T), as submitted by the committee, were referred to letter ballot for advancement to standard, one negative vote being cast on this recommendation.

The Tentative Specifications for Merchant Bar Iron (A 85 – 21 T) were referred to letter ballot for adoption as standard.

The committee concurred in the action recommended by Committee A-1 on Steel on the advancement to standard of the Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 22 T) to supersede the Standard Specifications for Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 21) the Standard Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives (A 38 – 21) and the Standard Specifications for Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service (A 52 – 18).

The report of the committee as amended was, on motion, adopted.

A paper entitled "Chain: Effect of Proofing and Annealing on Brittleness in Large Chain Links," by C. G. Lutts, was presented by the author and discussed.

The report of Committee A-7 on Malleable Castings was presented by the chairman, W. P. Putnam. The proposed revisions of the Standard Specifications for Malleable Castings (A 47 – 19) published in 1922 were, on recommendation of the committee, referred to letter ballot for adoption as standard.

The report of the committee was, on motion, adopted.

At this point, the meeting recessed to meet with the Fourteenth Session, which was being held simultaneously, for the announcement of the winners and the presentation of the prizes of the Golf and Tennis Tournaments.

The report of Committee A-3 on Cast Iron was then presented by the chairman, Richard Moldenke. The Tentative Specifications for High-Test Gray-Iron Castings (A 88 – 22 T) were referred to letter ballot for adoption as standard as recommended by the committee.

The Tentative Specifications for Chilled Cast-Iron Wheels (A 46 – 22 T) were referred to letter ballot for adoption as standard with the following revisions approved at the meeting, subject to a subsequent letter ballot in Committee A-3:

Section 2.—Change the last item to read as follows:

Sulfur, per cent, maximum:
0.17 for 1923 to 1924, incl.
0.16 " 1925 to 1926, "
0.15 " 1927 to 1928, "
0.14 " 1929 and thereafter.

Section 9.—Change to read as follows:

"The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works."

Committee A-3 has subsequently reported the letter ballot on this recommendation as follows: Affirmative, 49; Negative, 0; Refrained from voting, 17.

The Tentative Specifications for Foundry Pig Iron (A 43 – 22 T) were referred to letter ballot for adoption as standard with the following revisions approved at the meeting and subject to subsequent letter ballot in Committee A-3:

Section 2.—Change to read as follows:

"(*a*) The pig iron shall conform to the chemical requirements specified by the purchaser at the time of purchase, with the following permissible variations from the specified percentage in the case of pig iron intended for the manufacture of Gray-Iron Castings.

Silicon	0.25 per cent and below
Manganese	0.30 " " " "
Phosphorus	0.15 " " " "
Sulfur	not over specified percentage.
Total Carbon	not less than specified percentage.

"(*b*) In the case of pig iron for making steel and malleable iron castings, a maximum percentage of phosphorus and either a maximum or minimum percentage of manganese may be specified."

To the appendix, which is a recommendation and not a part of the specifications, add the following to the code symbols:

SILICON	TOTAL CARBON	PHOSPHORUS
3.75 per cent Ld	4.00 per cent Cy	1.75 per cent Pd
4.00 " " Lf		2.00 " " Pf

Committee A-3 has subsequently reported the letter ballot on this recommendation as follows: Affirmative, 48; Negative, 2; Refrained from voting, 16.

These specifications are a substitute for the present standard specifications of the same title (A 43 – 09).

The report of the committee was, on motion, adopted.

Papers entitled "Recent Investigations on Cast Iron for Pipe," by Richard Moldenke, and "The Standard Test Bar for Cast-Iron Pipe With Special Reference to Its Progressive Deflection," by J. T. Mackenzie, were presented by the authors and discussed jointly.

There being no further business, the Chair declared the Twenty-seventh annual meeting adjourned *sine die.*

FOURTEENTH SESSION—FRIDAY, JUNE 27, 8 P. M.

On Concrete and Reinforced Concrete

(Held simultaneously with the Thirteenth Session)

Cloyd M. Chapman in the chair.

The report of Committee C-9 on Concrete and Concrete Aggregates was presented by the chairman, A. T. Goldbeck. In addition to the report as preprinted the committee presented an addendum which recommended the revision of the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 22) to make the requirements for tolerances on wire diameter and sieve opening given in the methods agree with the suggested requirements appearing in the report of Committee E-1. This revision required a nine-tenths vote for submission to letter ballot. The revision was referred to letter ballot for adoption as standard.

The report of the committee as amended was, on motion, adopted.

A paper entitled "Calcium Chloride as an Admixture in Concrete," by D. A. Abrams, was presented by the author and discussed.

The Thirteenth and Fourteenth Sessions then met jointly for the announcement of the winners and the presentation of the prizes of the Golf and Tennis Tournaments, E. D. Boyer making the announcements on behalf of the Entertainment Committee. The A.S.T.M. championship golf cup and medal for the low score was won by M. M. Upson of New York City. The A.S.T.M. championship tennis cup and medal was won by A. G. Blakeley of Pottsville, Pa. Other prize winners in golf and tennis were: J. H. Chubb, J. H. Young, A. F. Braid, E. D. Boyer, N. B. Hoffman, W. B. Price, D. W. Mulford, G. H. Clamer, L. M. Rossi, J. L. Schueler, Alexander Milne, Powell Pardee, J. G. Detwiler and L. P. Nemzek.

The report of Committee C-2 on Concrete and Reinforced Concrete was presented by the chairman, Richard L. Humphrey, in conjunction with the Report of the Committee on Specifications for

Concrete and Reinforced Concrete. In presenting the report on Specifications for Concrete and Reinforced Concrete, the chairman called upon A. T. Goldbeck and D. A. Abrams to present those portions dealing with materials and proportioning and mixing. He further called on F. R. McMillan to present that portion of the report dealing with details of construction and design and on S. C. Hollister on design of columns.

A paper entitled "The Camden and Newark Bay Concrete Tests," by W. A. Slater, was presented by F. R. McMillan. The report of the Joint Committee and the paper on the Camden and Newark Bay tests were discussed jointly.

There being no further business, the Chair declared the Twenty-seventh annual meeting adjourned *sine die.*

AMERICAN SOCIETY FOR TESTING MATERIALS

ORGANIZED IN 1898.
INCORPORATED IN 1902.

PROCEEDINGS

PART I

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

ANNUAL ADDRESS BY THE PRESIDENT, GUILLIAEM AERTSEN

June 25, 1924.

Your President is hampered by outstanding facts in addition to his general lack of speech-making ability. His predecessors have been familiar with the use or consumption of a variety of materials, all of which have interested in general, as well as in particular, the membership of the Society, while he is tolerably familiar with only one branch of your Society's interests, that of steel. It would therefore seem at least prudent for him to confine his remarks to that subject.

What is steel? We need not pause for replies, but take it that they would be many and contradictory, or at least differing to such an extent as would require more time than is at our disposal for their enumeration without argument for or against.

The dictionary definitions of steel vary with their dates, but it is fair to assume that all such definitions would be predicated upon the combination of iron with its various alloying elements. The importance of these combinations is indicated by the fact that the specifications of our Society involving iron and steel number 77, while those having no reference to iron and steel number 162.

Let us disregard for the moment all those materials which do not contain iron. Let us go a step further and disregard all such combinations as are based upon iron without its union with such constituents as would cause it to be called "steel." That brings us again to the question of "What is Steel?"

As we are an American society, it is fair to confine our source of definitions to the English language and we cannot be criticized if we accept Webster as our authority. Webster now seems to include in "steel" all varieties of iron between wrought iron and cast iron, roughly subdividing it into three grades of hardness for commercial purposes: Mild steel containing less than 0.15 per cent of carbon; medium steel containing from 0.15 to 0.30 per cent of carbon; and hard steel containing more than 0.30 per cent of carbon.

A more exact metallurgist has defined steel as "Iron which is malleable at least in some one range of temperature and in addition is either (*a*) cast into an initially malleable mass; or (*b*) is capable of hardening greatly by sudden cooling; or (*c*) is both so cast and capable of so hardening."

I do not know of cast steel having been utilized by our ancestors either commercially or for war purposes previous to the time of Benjamin Huntsman, about 1740 A. D., who melted in crucibles blister bar which had absorbed carbon in the process of cementation and who forged from the ingots thus obtained, weighing only a few hundred pounds each, weapons and similar articles, whose composition was uniform and thus differed from the articles forged from carbonized bars of wrought iron.

Previous to the production of cast steel by Huntsman, steel articles contained carbon absorbed by wrought iron during its exposure, while hot, to carbonaceous material. The qualities due to temper, etc., which weapons and similar articles possessed were due as much to the treatment which they received after forging as to the composition of the materials from which they were made.

The mysterious exercises accompanying the tempering of swords and other carefully forged weapons can be analyzed and justified by the conditions accompanying the semi-religious rites which were observed. The blood temperature of a young healthy human being seemed to be pretty close to what was needed in properly hardening and tempering a sword or other weapon made from the materials available in India hundreds of years ago. This, not superstition, really justified the sword makers in their behavior, and the body of a young female slave seemed a proper apparatus to be used in chilling, gradually or suddenly, the weapon which would afterward adorn the person of a great commander and by him be used to enhance the glory of his country, his God, and, most important of all, himself.

We may disregard the traditional records of the production or use of iron in India as early as 1370 B. C. and in China as early as 2200 B. C. Iron implements so made were converted into steel, or its imitation, about this time, but such conversion may be disregarded.

Confining our attention to the product of our own country, America, as brought to the notice of our elder brothers east of the Atlantic, we may accept as facts that:

The first ship load of American iron ore was sent to England about 1608 A. D.

The first pig iron was made in Virginia about 1621 A. D.

The first steel rails, bessemer, were made in Wales about 1857, and shortly after that, in 1861 A. D., the first bessemer steel was made in Pittsburgh.

Although iron seems to have been made in Belgium during the first century A. D., its production subsequently became a lost art; but steel, as well as iron, was made in Britain by the Catalan process previous to 400 A. D.

About 1740 A. D. was brought into actual practice Benjamin Huntsman's process of melting in crucibles bar iron or steel after its production as blister-bar in cementation furnaces.

This gave its name to the manufacture of crucible steel which was known as "Warranted Cast Steel." Its imitation in the Siemens open-hearth furnace more than a century afterward led to acrimonious discussion in which was questioned the right of the then modern steel makers to use for open-hearth steel the title which had hitherto been confined to crucible steel. This discussion, founded upon honest difference of opinion, continued long, and only a few years ago crucible steel makers questioned the right of competitors to apply the term "Warranted Cast Steel" to any metal not made in crucibles.

A few years ago a learned member of our Society submitted to a companion association, whose object is closely limited to the treatment of steel after its production, a paper which has a title similar to our present subject, "What is Steel?" The last sentence of his paper may be almost considered an answer to this title. It reads, "I don't know."

Is it too much to prophesy that our Society will before many years be called upon to decide officially between what is steel and what is iron? The methods of manufacture may be the same, carbon may be eliminated from the discussion as being present in neither or in both, and your humble speaker will feel that he has not made a useless noise if he provokes discussion which may result in useful conclusions and perhaps an answer to this question.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The Executive Committee offers the following report of general Society activities for the past year:

Membership.—Membership statistics for the past year are shown in the following table:

	1923 Annual Meeting	1924 Annual Meeting	Losses				Additions		Totals		
			Transfer	Resignation	Dropped	Death	Transfer	Election	Loss	Gain	Increase
Honorary Members..........	3	3	..	..	..	..	..	..	..	..	..
Members....................	3113	3387	..	127	93	13	47	460	233	507	274
Junior Members.............	124	91	47	7	10	1	..	32	65	32	33[a]
Total....................	3240	3481	47	134	103	14	47	492	298	539	241

[a] Decrease.

The membership of the Society at the time of this annual meeting is 3481. The net increase in membership is 241 compared with 210 for the year ending with the 1923 annual meeting and 122 for the year ending with the 1922 annual meeting. This very satisfactory record is due in large part to the cooperation of the standing committees in using their organized efforts to secure new members. The details of this work have been reported from time to time in the A.S.T.M. Bulletin and it will be recalled that during the calendar year of 1923 there were secured 532 new members, a Society record. The interest of the standing committees and of the members individually has been very gratifying, and the Executive Committee wishes to express its appreciation of the efforts that have been and are now being made along this important line.

The Society has suffered the loss by death of fourteen members, among them being Robert W. Hunt, a Past-President and Honorary Member of the Society, Albert Ladd Colby, one of the Charter Members of the Society and long active in its work, and D. M. Buck, a member of the Executive Committee for the current term and prominently identified for years with the Society's activities in the field of corrosion of metals. The names of the deceased members are:

J. A. Beckett
D. M. Buck
Albert Ladd Colby
H. E. Diller
P. H. Dudley
J. C. Fitzsimmons
W. J. Francke
R. M. Howe
Robert W. Hunt
W. C. Marckworth
P. C. McIlhiney
F. J. Napolitan
W. T. Sears
C. H. Stone

Membership growth since the organization of the Society is shown in Fig. 1.

Standing Committees.—The standing committees of the Society have been unusually active and their annual reports to be presented at this meeting form one of the most inspiring records of achievement by the committees ever recorded in the annals of the Society. Of the 41 standing committees, four are not presenting reports this year and eight are presenting more or less formal reports of progress. The reports presented comprise approximately 670 pages and include recommendations for proposed revisions in 50 standards (of which 17 have been previously reported), adoption of 41 tentative standards as standard, acceptance of 40 proposed new standards as tentative, and proposed revisions in 41 tentative standards to be continued as tentative.

The Executive Committee has requested the standing committees to include hereafter in their annual reports, as a matter of important record and for the information of the Society generally, appropriate statements giving the essential information regarding the origin of proposed new specifications and the reasons for proposing revisions in existing specifications. It is believed that the current and historical value of our committee reports will be enhanced in the proportion that such information is made a part of the official records.

The work of Committee E-1 on Methods of Testing in reviewing methods of test prepared by the various standing committees has emphasized the importance of having the standing committees submit the principal data upon which proposed methods of test or revisions thereof have been based. While these basic data have frequently been given in the committees' reports to the Society, this has not always been done. It has been suggested that such data if extensive and in great detail need not be published *in extenso* and that the principal purpose will be served if they are made available to Committee E-1.

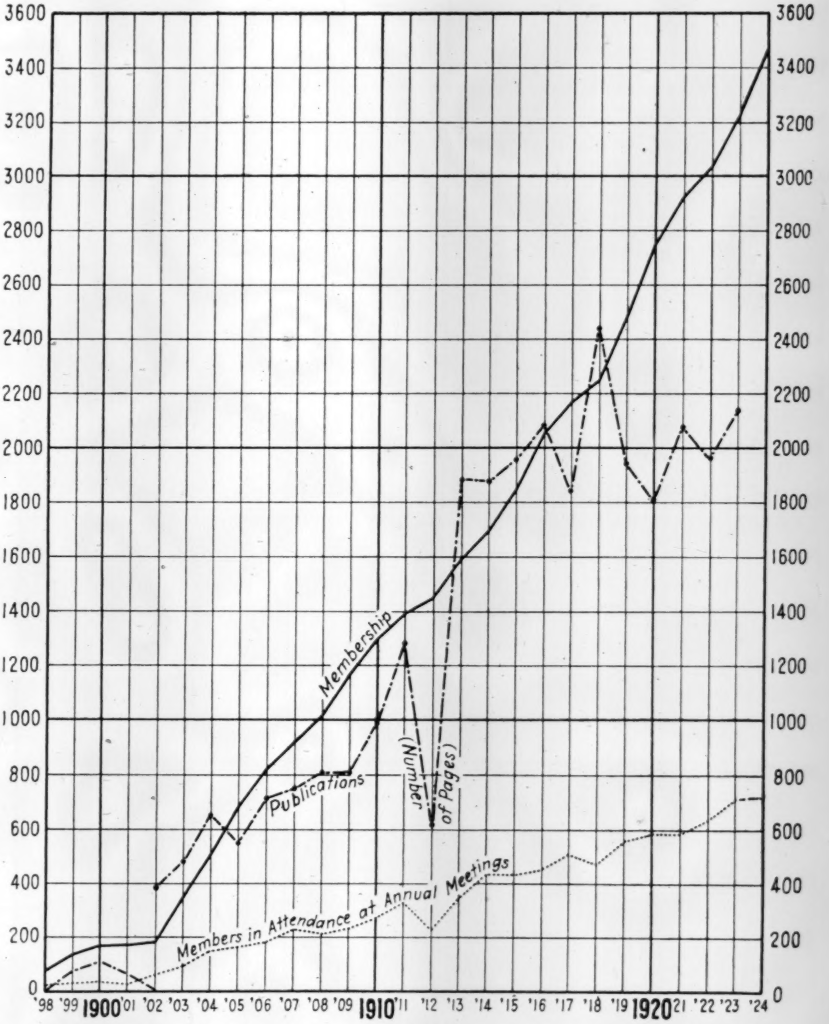

FIG 1.—Membership and Publications Chart.

NOTE.—The initial curve for publications (1898–1902) refers to the publications of the American Section of the International Association for Testing Materials. The marked drop for 1912 in the "publications" and "members in attendance at annual meetings" curves is due to the fact that the Sixth Congress of the International Association was held in New York in September, 1912, and that the activities of the American Society for that year were accordingly restricted to committee reports and administrative business.

The scope of work of Committee D-8 on Waterproofing Materials has, on its request, been broadened to include bituminous roofing materials and at the same time restricted to bituminous waterproofing. The title of the committee is now Committee D-8 on Bituminous Waterproofing and Roofing Materials.

During the year, two new committees were organized: Committee A-9 on Ferro-Alloys and Committee D-16 on Slate. The former committee, organized last November, is reporting substantial progress at this meeting. The latter committee, organized in January of this year, is still serving under temporary officers but has outlined a program of work that will enable the Society to accomplish results of value in the study of properties of and methods of testing slate. The organization of this committee is a direct result of the Topical Discussion on Slate held at the last annual meeting.

The Executive Committee has under consideration the organization of a new standing committee on Glue. The Topical Discussion on the Testing of Glue at the last annual meeting developed considerable interest, and conferences with the National Association of Glue Manufacturers and leading producers and consumers of glue among the members of the Society have been favorable to the formation of such a committee.

Mention was made last year of the suggestion of one of the standing committees of the Society that a Committee on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys be formed. After conferring with the several standing committees having some interest in this general subject, it was decided to defer the organization of such a committee and to arrange instead for a general discussion of the subject in the form of a symposium. Committee E-6 on Papers and Publications was accordingly requested to arrange for such a symposium, and two sessions of the present annual meeting are being devoted to it.

Mention should be made of the successful three-day session at Pittsburgh in March of this year at which seven of the metals committees of the Society held their spring meetings. Excellent provisions were made for the large number of sub-committee meetings that were necessary; the meetings were well attended and the opportunities for social intercourse were such as to make the meetings of greater interest and value than ever. The general consensus of opinion of the members individually as well as of the committees officially was that the plan of establishing "committee weeks" has many advantages, and the Executive Committee wishes to encourage the continuation of this plan of meeting for the metals committees and its extension among other groups of our standing committees whose activities are related both by subject matter and duplication of personnel.

Publications.—The regular publications during 1923 were the Proceedings, Supplement to the 1921 Book of Standards, and the Year Book. The comparative statement of the volume of regular publications during the past three years is as follows:

	1921; PAGES	1922, PAGES	1923, PAGES
Proceedings	1197	1614	1689
Book of A.S.T.M. Standards	890	....	....
Year Book (Membership List)	....	304	326
Supplement to Book of Standards	....	54	126
Supplement to Year Book	32	....	....
Total	2119	1972	2141

In addition, the Society published in 1923 the Book of A.S.T.M. Tentative Standards (859 pages), which in accordance with the policy of the past three years is the only publication containing all the tentative standards of the Society. It is furnished to members upon order at special prices, and the demand for it has steadily increased since its first publication in 1917.

The A.S.T.M. Bulletin has been issued at approximately quarterly intervals during the year. There have also been printed in addition four circulars to members.

There was also published during the year, at the suggestion of Committee D-13 on Textile Materials, a pamphlet of 80 pages containing A.S.T.M. Specifications and Methods of Test for Textile Materials with Reports and Papers Relating Thereto. This pamphlet constitutes a complete résumé of the Society's activities and accomplishments in the field of textile materials up to 1923 and is being used most effectively by the Textile Committee in carrying on its work.

The bound publications issued since the last annual meeting, not including preprints, total 3000 pages.

Finances.—The annual statement of the finances of the Society follows in the form of the report of the auditors for the fiscal year, January 1, 1923, to December 31, 1923.

The surplus on December 31, 1923, was $37,133.03 and includes $1300 life membership dues, $467.17[1] for rent paid in advance, $3131.32

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[1] When the Society established its headquarters in the fall of 1919, it entered into an agreement with the Engineers' Club of Philadelphia by which it was to pay the cost of necessary alterations to the Club building, this sum to be accepted by the Club as advance payment of rent at the rate of $1000 a year. This agreement became effective on January 1, 1920. The total amount thus paid by the Society was $4467.17, of which $4000 has been charged off in the four years ended December 31, 1923, leaving the amount on that date of $467.17 as an asset.

for furniture and fixtures and $6894.61 set aside as a sinking fund toward defraying the cost of the 1924 issue of the Book of Standards. (To this latter sum has been added $2400 invested this year from the cash balance of $5139.72 as of December 31, 1923.)

Receipts from the sale of the Society's publications, $22,024.90, are approximately 30 per cent of the Society's gross receipts for the year, and in that respect compare very favorably with the past two years. These increased receipts are indicative of the wider distribution and use of the Society's publications and standards; and it is also to be noted, as has been emphasized by the Executive Committee in other reports, that this important source of income has enabled the Society to maintain and indeed to increase the volume of publications of Proceedings, Standards and Tentative Standards in the face of present printing costs. The importance of healthy, active growth of the Society's membership to provide in part the increased funds to keep pace with the continual spread of Society activities is clearly evident and justifies the emphasis that the Executive Committee is placing on membership growth.

Inventory of Publications in Stock.—In the foregoing financial analysis no account has been taken of the assets of the Society in the form of publications in stock. The inventory on May 20, 1924, may be summarized as follows:

	NUMBER OF COPIES
Proceedings	7928
1921 Book of A.S.T.M. Standards	1295
Index (Vols. I–XII, incl.)	583
(Vols. XIII–XX, incl.)	733
Reports of Committee D-1 (1903–1914, incl.)	287

Preprint Policy.—A year ago a new plan of distributing preprints was adopted, by which committee reports and papers printed for the meeting were sent in advance only to those members who requested them, a complete set of preprints being furnished each member attending the annual meeting, as in previous years. This plan has apparently met with a very general approval of the membership and resulted last year in a saving in cost of preprints over 1922 of nearly $2900. The same plan has been followed in the distribution of preprints for the present meeting.

Headquarters.—To provide for increased facilities required by continued growth and expansion of the Society activities and to better care for meetings of the Society's committees, the Society has recently enlarged its headquarters by acquiring the fourth floor of the

REPORT OF AUDITORS FOR THE FISCAL YEAR JANUARY 1, 1923, TO DECEMBER 31, 1923.

JOHN HEINS AND CO.
PUBLIC ACCOUNTANTS AND AUDITORS

PHILADELPHIA, December 31, 1923.

AMERICAN SOCIETY FOR TESTING MATERIALS,
MR. C. L. WARWICK, *Secretary-Treasurer,*
Philadelphia, Pa.

Dear Sirs:

We respectfully report that we have made an audit and examination of the books and accounts of your Society for the six months ended December 31, 1923, having previously made a similar audit and report for the preceding six months ended June 15, 1923, and at both audits found the accounts to be correct and to be in their usual excellent condition.

We submit balance sheet as of December 31, 1923, as also a statement of cash receipts and disbursements for the twelve months then ended.

We have verified the transactions set forth in the budget record for the last six months as also for the six months ended June 15, last, as reported in ours of June 18 and found the same to be correct.

We have verified by actual inspection and count the securities as listed on the Balance Sheet.

Respectfully submitted,
(Signed) JOHN HEINS AND CO.

BALANCE SHEET AS OF DECEMBER 31, 1923.

ASSETS.

Cash		$5,139.72	
Investments:			
$13,000 U. S. Liberty Loan Bonds, 4th $4\frac{1}{4}$'s	$12,486.03		
4,200 U. S. Liberty Loan Bonds, 4th $4\frac{1}{4}$'s, reserve for 1924 Book of Standards	3,894.61		
1,300 U. S. Liberty Loan Bonds, 4th $4\frac{1}{4}$'s, held for Life Membership Fund	1,227.45		
3,000 P. R. R. Equipment Bonds, 6's, due 1933	3,052.56		
3,000 U. S. Treasury Certificates due Sept. 15, 1924, reserve for 1924 Book of Standards	3,000.00		
		23,660.65	
Accounts Receivable:			
For Publications	$2,866.87		
Members for 1923 dues	2,290.29		
Members for binding	45.00		
		5,202.16	
Rent paid in advance		467.17	
Furniture and Fixtures		3,131.32	
			$37,601.02

LIABILITIES.

Members dues paid in advance	$464.99		
Members binding paid in advance	3.00		
		$467.99	
Life Membership	$1,300.00		
Surplus	35,833.03		
		37,133.03	
			$37,601.02

MISCELLANEOUS FUNDS.

In addition to the above cash the Secretary-Treasurer has on hand the following funds:

Committee A-5 on Corrosion of Iron and Steel	$1,934.11	
Committee C-1 on Cement	2,013.78	
Committee C-9 on Concrete and Concrete Aggregates	598.69	
Committee C-10 on Hollow Building Tile	202.64	
Committee D-1 on Preservative Coatings	64.68	
Joint Committee on Investigation of Phosphorus and Sulfur in Steel	134.60	
		$4,948.50

RECEIPTS AND DISBURSEMENTS.
JANUARY 1, 1923, TO DECEMBER 31, 1923.

Cash on hand, January 1, 1923			$3,495.03

RECEIPTS.

Current dues	$47,324.09		
Past dues	1,011.94		
Advance dues	448.49		
		$48,784.52	
Sale of Publications:			
Separate Standards	$3,359.90		
Book of Standards	3,195.98		
Book of Tentative Standards	4,868.94		
Proceedings	3,555.60		
Index to Proceedings, Vols. XIII–XX	1,483.38		
Miscellaneous	5,561.10		
		22,024.90	
Binding (Members)		917.80	
Sale of right to reprint Standards		600.00	
Authors' reprints		164.12	
Sale of Certificates of Membership		56.60	
Interest on deposits and investments		1,931.84	
Accrued interest		219.81	
Excess remittances		89.60	
Miscellaneous		16.19	
Total receipts		$74,805.38	74,805.38
			$78,300.41

Brought forward		$78,300.41

DISBURSEMENTS.

Publications	$35,889.96	
Salaries	19,646.13	
General Office Expenses	4,582.22	
Expenses, Standing Committees	1,490.16	
Expenses, Annual Meeting	1,897.83	
Expenses, Nominating Committee	47.18	
Traveling Expenses, Executive Committee	604.47	
Rent and Insurance, Storage Rooms	321.60	
Rent, Additional Room	120.00	
Headquarters' Maintenance	146.41	
Furniture and Fixtures	653.32	
Expenses, Enlargement of Headquarters	2,815.00	
Certificates of Membership	24.50	
American Engineering Standards Committee	1,500.00	
Annual Tables of Constants and Numerical Data	100.00	
Investments	3,000.00	
Accrued interest	219.81	
Refund of excess remittances	89.60	
Miscellaneous	12.50	
Total disbursements	$73,160.69	73,160.69
Cash on hand December 31, 1923		$5,139.72

FINANCIAL CONDITION AT CLOSE OF FISCAL YEARS 1919–1923, INCLUSIVE.

Fiscal Year	ASSETS.					Liabilities.	Surplus [b]
	Cash Balance	Investment	Accounts Receivable	Advance Rent and Furniture and Fixtures	Total	Accounts Payable [a]	
1919	$294.70	$15 601.58	$3 415.40	$3 600.00	$22 911.68	$417.25	$22 494.43
1920	265.05	17 608.09	3 823.90	5 897.48	27 594.52	2 608.50	24 986.02
1921	3 819.07	17 608.09	5 218.35	5 121.34	31 766.85	770.00	30 996.85
1922	3 495.03	20 660.65	5 242.65	4 293.09	33 691.42	663.25	33 028.17
1923	5 139.72	23 660.65	5 202.16	3 598.49	37 601.02	467.99	37 133.03

[a] These sums represent dues and publications paid in advance and do not include any unpaid bills except for 1920, a loan of $2200 from the Girard Trust Company.

[b] These items include $1300 on account of Life Memberships.

property at 1315 Spruce Street, Philadelphia, on a six-year lease from the Engineers' Club of Philadelphia expiring December 31, 1929. This space is directly above the Society's present quarters on the third floor and with the present quarters gives a total floor space of approximately 2300 sq. ft. The lease on the third floor rooms, which would have expired at the end of 1924, has been renewed to December 31, 1929. The rental for the newly acquired fourth floor for this year is $850. The rental on the present quarters for the present five-year lease has been $5000, of which $4467.17 was paid in advance in 1920, representing cost of alterations which was credited to the Society as rent paid in advance at the rate of $1000 per annum. There is thus a balance due in 1924 for rental of the present quarters of $532.83, making a total rental item for this year of $1382.83. Beginning with 1925, the Society's annual rental expenses for headquarters will be $2400.

The expense of remodeling the fourth floor into suitable quarters, which under the terms of the lease has been assumed by the Society, has been $3338.96. This sum, of which $2815 has been paid from current receipts for 1923, includes certain alterations necessary in the third floor rooms, but does not include the cost of new furnishings. Spread over a period of six years, the alteration costs represent approximately $550 per year, which bring the effective annual rental up to about $2950—a reasonable figure considering existing rentals in Philadelphia.

The Executive Committee feels that the question of Society headquarters is in this way very satisfactorily taken care of for a period of six years. The new quarters have been completely furnished. Two committee rooms have been provided on the fourth floor, so arranged that they can be thrown into one large room capable of seating all but the largest of the Society's committees. The Editorial and Publication Department of the Society occupies the remainder of that floor, giving that rapidly growing department much needed space, relieving the congestion in the main office and greatly improving the appearance of the Society's rooms.

The facilities offered by the Society's headquarters for meetings of committees and their sub-committees have been very generally used. During the period from June, 1923, to June, 1924, there were sixteen committee meetings, fifty-seven sub-committee meetings, and twelve meetings of committees of other societies, or a total of eighty-five. The Executive Committee wishes to have the committees and members of the Society make use of the headquarters as much as possible.

The Annual Meeting.—The ever-increasing volume of business coming before the Society at its annual meetings, in the shape of committee reports, papers and general discussions, have had the inevitable effect under the general plan of "single" sessions of making the meetings of the Society longer than has been thought desirable. For the past two years it has been found necessary to hold two groups of simultaneous sessions. The arrangement of the program in the past years has brought the metals and non-metals groups of the Society for the most part at opposite ends of the program, having the tendency to "split" the membership of the Society rather sharply. Moreover, with sessions of the Society morning, afternoon and evening on practically every day, it was impossible to hold committee meetings without seriously interfering with these sessions. These developments have given the Executive Committee no little concern.

In an effort to meet these conditions, the program for this annual meeting, on the recommendation of the Committee on Papers, has been arranged so that two sessions are held simultaneously at all but two periods at which the Society meets. The program on metals extends throughout the meeting and the sessions on non-metals have been scheduled against the metals sessions with little conflict of subject matter and group interest. In this way the meeting has been shortened as much as possible, consistent with opportunity for proper consideration of the reports and papers. The several groups of interests in the Society are brought more closely together, thus providing opportunity for extending acquaintance and good fellowship among our members. With the exception of Tuesday, there will be no afternoon session of the Society, these periods being reserved for recreation and committee meetings. Thus, with Monday afternoon and evening, Tuesday morning, and Wednesday and Thursday afternoons available for committee meetings, these meetings can now very generally be held without conflicting with regular Society sessions—something that every committee member will appreciate.

The problems involved in the application of this plan have been carefully studied by the Committee on Papers and a well-balanced program has resulted. The verdict of the meeting itself will determine the ultimate value of this departure from the practice of recent years.

Joint Meeting with the American Society of Mechanical Engineers.—On May 29, at Cleveland, the Society met jointly with the American Society of Mechanical Engineers during its spring meeting to discuss "The Effect of Temperature Upon the Properties of Metals." The Society was invited by the A.S.M.E. to join with it in a discussion of this subject, the importance of which had become evident through the activities of the Sectional Committee on Standardization of Pipe Flanges and Fittings, of which the A.S.M.E. is sponsor under the Rules of Procedure of the American Engineering Standards Committee. The Society had taken an active part in the discussion in this sectional committee on materials specifications; and since the subject of the discussion was within the immediate scope of A.S.T.M. activities, the Society was asked to arrange the program of the meeting. This was done by Committee E-6 on Papers and Publications with the aid of a special committee acting in an advisory capacity. The introductory papers were preprinted for the Cleveland meeting by the Society, in the form of a bound pamphlet of 136 pages.

The meeting was a pronounced success; it was well attended and the discussions were enlightening and valuable. The means for the development of further knowledge on this important subject are now under consideration by the two societies.

Research in the Society.—The matter of developing more fully that function of the Society designated in its Charter as "the Promotion of Knowledge of the Materials of Engineering," upon which discussion was directed at the annual meeting last June, has continued to receive the consideration of the Executive Committee. As emphasized at that meeting, it is important that the Society should consciously, in as systematic and concerted a way as possible, go about the task of extending the knowledge of engineering materials, their properties, their performance in service, and the correlation of properties and performance that determine the suitability of various materials for specific services. The main emphasis in the Society's work in the past twenty years has been upon standardization of specifications and methods of testing, and necessarily so. We have created the machinery and procedure for this purpose; and while that work should be continued as vigorously as ever, the emphasis for the immediate future at least should be on the promotion of knowledge of engineering materials.

Since research underlies the promotion of knowledge and since work of this character is being carried on at present by many of the Society's committees in varying degrees, the Executive Committee has authorized the formation of a small committee to be known as the "Committee on Correlation of Research in the A.S.T.M." The personnel of this important committee is at present under consideration.

This committee will not be a research committee in the sense of actually conducting research. It will be charged to devise ways and means by which the whole question of research activities in the Society's committees and in other channels may be advanced along the soundest lines, to the end that the Society will contribute in increasing measure to the knowledge of materials of engineering. The committee will advise the Executive Committee in all matters relating to research, and to it will be referred for consideration proposed studies, of which several are pending.

The Executive Committee believes that an examination and evaluation of the present agencies in the Society for the promotion of knowledge of materials must first be considered by this new committee. These are essentially:

1. The present standing committees, all of which are engaged in this work in varying degrees.
2. Joint committees with other bodies.
3. Investigations and researches by members of the Society presented in the form of technical papers and discussions.
4. Dissemination of knowledge through Society publications.

In devising ways and means of further development, the committee will have three major problems to consider:

1. The stimulation of existing agencies and their possible modification.
2. A survey of the existing knowledge of engineering materials to determine those fields wherein further knowledge is essential and of greatest importance.
3. What new agencies, if any, are needed in the Society for the development of this work? Should research and standardization be handled in one committee, and if so under what conditions? Should separate research committees be formed, and if so what should be their relation to the existing committee organization and to the Committee on Correlation of Research?

The matter of financial support is important. The Executive Committee believes the Society should offer every possible encouragement in the way of publication of researches and investigations in the properties of materials, and liberal appropriations from current funds should be made available for publication expenses. In addition, a fund should be established, of which the income should be used for administrative expenses of research activities within the Society, which may be considerable in view of the large field now covered by our activities. Finally, the financial support of specific investigations must be worked out for each individual case.

The Executive Committee believes—and is confident that the members share that belief—that this subject is one of the most important that we are facing to-day and that the solution of the problems involved will vitally affect the future development of the Society.

American Engineering Standards Committee. — Past-President C. D. Young has been re-appointed as the representative of the Society on the Standards Committee for the ensuing term of three years. Past-Presidents J. A. Capp and A. A. Stevenson are the other two representatives on this committee. Mr. Capp is Vice-Chairman of the Committee and is the Society's representative on the A.E.S.C. Executive Committee.

In view of the fact that the members are kept acquainted through the A.S.T.M. Bulletin with the activities of the Society and its committees in relation to the work of the American Engineering Standards Committee, only matters of principal importance in this connection will here be reported.

At the time of the last annual report, 50 standards of the Society had been submitted to the Standards Committee for approval. Since the last annual meeting ten additional standards have been submitted, as follows:

Standard Specifications for:

Cast-Iron Pipe and Special Castings (A 44 – 04);
Block for Granite Block Pavements (D 59 – 22);
Materials for Cement Grout Filler for Brick and Stone Block Pavements (D 57 – 20);
Hard-Drawn Copper Wire (B 1 – 23);
Medium Hard-Drawn Copper Wire (B 2 – 15);
Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 21).

Standard Methods of:

Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 20);
Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (D 75 – 22);
Test for Specific Gravity of Coarse Aggregates (D 30 – 18);
Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials (D 55 – 19).

At this time the total number of standards thus submitted is 60, of which one has been approved as American Standard, 29 as Tentative American Standard, and 30 are at present under consideration. Of the 30 that have been approved, the Society has been designated as sponsor for 22 and jointly with other interested organizations as sponsor for three. Such sponsorships that have been assigned since the last annual report include those for Specifications for Refined

Wrought-Iron Bars (A 41 – 18), for Wrought-Iron Plates (A 42 – 18) and for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 21).

During the year there has been organized under the procedure of the Standards Committee two sectional committees for which the Society is one of several joint sponsors. The Sectional Committee on Fire Tests of Materials and Construction, under the joint sponsorship of the U. S. Bureau of Standards, the Fire Protection Group, and the A.S.T.M., was organized at a meeting in New York on May 2. The scope of the work of this sectional committee is as follows:

> "Study of the present Tentative American Standard Specifications for Fire Tests of Materials and Construction (A.S.T.M. C 19 – 18) with a view to adopting necessary amendments thereof including amendments outlined in the 1922 report of Committee C-5 on Fireproofing of the A.S.T.M.
>
> "Extend the standards to include specifications for fire tests of materials and structural units which constitute permanent integral parts of a finished building."

The personnel of the sectional committee has been submitted to the Standards Committee for approval. The Society's representative on the sectional committee is Ira H. Woolson, who is also chairman of our Committee C-5 on Fireproofing. Other members of Committee C-5 are on the sectional committee, and the work of our committee will be closely correlated with that of the larger sectional committee. Mr. Woolson has been elected as chairman of the sectional committee.

A sectional committee on Numbering of Steels was organized in Washington on May 8 under the joint sponsorship of the Society of Automotive Engineers and the A.S.T.M. This committee has been organized for the purpose of developing "a numbering system for forging, casting and structural steels, including plates, but not including tool steels, the numbering system to be based on definite specifications." The Society's representation on this sectional committee has been taken from the Sub-Committee on Nomenclature of Committee A-1 on Steel, and our three representatives are L. H. Fry, T. D. Lynch and H. H. Morgan. F. P. Gilligan, representing the S.A.E., is chairman of the sectional committee and Mr. Fry is secretary.

The Society has been requested by the Standards Committee to sponsor the organization of a Sectional Committee on Zinc Coating of Iron and Steel. Study of this problem having indicated the feasibility of tying in the present activities of Committee A-5 on Corrosion of Iron and Steel with this broader project—broader in the sense that it includes products and coatings not heretofore considered by our committee—the Executive Committee has accepted this invitation and will undertake the organization of the proposed sectional committee.

During the year the following appointments were made of representatives of this Society on sectional committees under the sponsorship of other organizations: T. D. Lynch and H. P. Tiemann as representatives on the Sectional Committee on Gears, under the joint sponsorship of the American Gear Manufacturers Association and the American Society of Mechanical Engineers; E. F. Kenney as representative, with F. N. Speller as alternate, on the Sectional Committee on Specifications for Materials for Use in the Manufacture of Special Trackwork, under the sponsorship of the American Electric Railway Association; E. J. Edwards and F. O. Kichline as representatives on the Sectional Committee on Bolt, Nut and Rivet Proportions, under the joint sponsorship of the Society of Automotive Engineers and the American Society of Mechanical Engineers; H. V. Wille and V. T. Malcolm as representatives on the Sectional Committee on Standardization of Pipe Flanges and Fittings, under the joint sponsorship of the American Society of Mechanical Engineers, Committee of Manufacturers on Standardization of Fittings and Valves, and Heating and Piping Contractors National Association; and Cloyd M. Chapman as representative on the Sectional Committee on Wood Poles, under the sponsorship of the Telephone Group.

Cooperation with U. S. Department of Commerce—Dictionary of Specifications.—Recent issues of the A.S.T.M. Bulletin have carried announcements of work that has been under way in the U. S. Department of Commerce for about a year, in the preparation of a dictionary or handbook of specifications for supplies purchased by federal, state and municipal governments and public institutions, with the object in view of bringing about the wider use of specifications by these agencies as a basis of purchase for supplies. In June, 1923, a conference of various national organizations interested in purchase specifications from the point of view of both producer and consumer was held for the purpose of organizing an Advisory Committee to cooperate with the Department of Commerce in this work. The Society is represented on this Advisory Committee by Vice-President W. H. Fulweiler. As a first step in this work a collection has been made of the available specifications formulated not only by the public purchasers throughout the United States, but also by the nationally recognized trade associations, technical societies and public utilities. These specifications have been classified tentatively under twenty-one major heads and many hundred sub-heads, about 29,000 classification index cards having been prepared for this purpose. A special effort is being exerted to render the collection of existing specifications and the classified index thereto as nearly complete and accurate as possible, so that the index can be used with confidence as the basis for the selection of specifications for inclusion in the handbook of specifications. The Advisory Committee is formulating a system for classifying these specifications.

Division of Simplified Practice of the U. S. Department of Commerce.—The Society has continued contact with the Division of Simplified Practice in connection with those of the Division's projects in which we are interested. Subjects that have come up during the year under this category are paving brick, hollow building tile, and road asphalt. The committees of the Society dealing with these subjects are expected to report upon them at this meeting.

Similarly, the Society has maintained contact with the work of the Central Committee on Lumber Standards, which has been organized through the efforts of the Division of Simplified Practice. The report of Committee D-7 on Timber contains reference to the features of this work that are of interest to the Society.

Division of Engineering, National Research Council.—President Guilliaem Aertsen has been appointed as the Society's representative on the Division of Engineering, National Research Council, for a term of three years, succeeding Past-President G. K. Burgess.

Through its representatives the Society has continued to maintain contact with the Division of Engineering and with certain of its committees, especially the activities of the Advisory Board on Highway Research, the Bureau of Welding and the Committee on Corrosion. On the latter committee J. O. Handy has been appointed a representative of the Society, succeeding D. M. Buck, deceased.

During the year the National Research Council organized a Committee of Apparatus Makers and Users, on which F. G. Breyer has been appointed as the Society's representative.

Cooperation with A.S.M.E. Boiler Code Committee.—Cooperation with the Boiler Code Committee of the American Society of Mechanical Engineers has been continued along the lines announced in last year's report and has resulted in very satisfactory agreement between the materials specifications in the Boiler Code of that Society and corresponding A.S.T.M. specifications. The revised edition of the Boiler Code has been issued. Many of the specifications are exactly the same as the corresponding A.S.T.M. specifications, and in the few in which there are some differences, these are for the most part of a minor character made necessary for various reasons. As a result of the cooperative work, certain of the Society's specifications are being revised, and it may be stated that, in general, material passing the several A.S.T.M. specifications will conform to the requirements of the revised Boiler Code. In view of the legal status the Boiler Code has in many of the states, this cooperative work has a great deal of significance to the Society, and the hearty spirit of cooperation that has been evidenced throughout the work of the joint committee handling this work is very gratifying.

Miscellaneous Joint Committees.—The Society has continued, through its representation, participation in the work of the various joint committees upon which it is represented. The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete is preparing a final report for its constituent organizations. This report was expected to be in final form for presentation at this meeting but this has not been found possible. When received, the report will be referred to the various standing committees for their comments.

Special mention should also be made of the work of the Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel, which is presenting reports on several investigations that have been completed during the year.

Other Cooperative Work.—Among other cooperative work that has taken place this year should be mentioned the following: In cooperation with the American Foundrymen's Association, through Committee A-3 on Cast Iron, consideration is being given to the methods of testing cast iron, particularly the Arbitration Test Bar and the adoption of an international standard. Cooperative relations have been established with the American Marine Standards Committee, which is interested in certain of the Society's standards applicable to the marine field. In this connection the specifications for condenser tubes have been the subject of a general conference. Committee A-1 on Steel through its appropriate sub-committee is cooperating with the American Railway Engineering Association in a revision of the Standard Specifications for Structural Steel for Bridges, with the result that as revised the specifications of the two organizations will now be in agreement. The Society is informally cooperating with the Building Code Committee of the Department of Commerce, having supplied the committee with various publications and having secured for the committee the criticisms and comments of some of our standing committees that have prepared specifications that have been used in their essentials by the Building Code Committee.

Respectfully submitted on behalf of the Executive Committee,

GUILLIAEM AERTSEN,
President.

C. L. WARWICK,
Secretary-Treasurer.

REPORT OF COMMITTEE A-1
ON
STEEL

During the past year Committee A-1 has held two meetings, one on October 5, 1923, and the second on March 14, 1924. A third meeting will be held prior to the presentation of this report to the Society, at which the report will be reviewed and other matters considered.

The Advisory Committee has held four meetings, at which matters concerning the general administrative affairs of the committee were considered.

The present membership of the committee is 165, of which 87 are classed as non-producers and 78 as producers.

Sub-Committees.—One new sub-committee has been appointed during the year: Sub-Committee XXII on Pipe Flanges and Fittings. This committee will deal with materials particularly intended for high pressure work, and is to work in cooperation with the Sectional Committee on Standardization of Pipe Flanges and Fittings, of the American Engineering Standards Committee, under the sponsorship of the American Society of Mechanical Engineers; the Committee of Manufacturers on Standardization of Fittings and Valves; and the Heating and Pipe Contractors National Association.

The committee has also appointed two representatives to serve on Committee A-4 on Heat Treatment of Iron and Steel.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards are presented first in summarized form together with an analysis of the letter ballot on each item. They are then referred to, where necessary, in greater detail, being grouped for convenience in the order of the respective sub-committees directly responsible for them.

I. Proposed Revisions in Standards.—The committee recommends that the revisions in the following standards, Nos. 1 to 20, inclusive, in Appendix I to this report, be referred to letter ballot of the Society for adoption as standard. The revisions are divided into two groups:

A.—Revisions proposed at the 1922 and 1923 annual meetings and now recommended for adoption by letter ballot.

B.—Revisions now proposed for the first time, which the committee recommends be referred to letter ballot of the Society by the necessary nine-tenths vote of the annual meeting.

The standard specifications in each group are as follows:

GROUP A

(*a*) *Revisions Recommended for Adoption as Presented in 1922*[1] *and 1923,*[2] *without amendment:*

For Steel Track Spikes (A 65 – 18).
For Boiler and Firebox Steel for Locomotives (A 30 – 21).

(*b*) *Revisions Recommended for Adoption as Presented in 1922*[1] *and 1923,*[2] *and amended in 1924 as indicated in the Appendix:*

For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 21).
For Welded and Seamless Steel Pipe (A 53 – 21).
For Automobile Carbon and Alloy Steels (A 29 – 21).
For Open-Hearth Steel Girder and High Tee Rails (A 2 – 21).
For Structural Nickel Steel (A 8 – 21).
For Structural Steel for Locomotives (A 10 – 21).
For Structural Steel for Cars (A 11 – 21).
For Steel Castings (A 27 – 21).
For Boiler Rivet Steel (A 31 – 21).
Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 14).
Methods of Chemical Analysis of Alloy Steels (A 55 – 15).

GROUP B

Revisions Proposed for First Time, and Recommended for Adoption:

For Carbon-Steel Rails (A 1 – 14).
For Low-Carbon-Steel Splice Bars (A 3 – 14).
For Quenched Carbon-Steel Track Bolts (A 50 – 21).
For Structural Steel for Bridges (A 7 – 21).
For Structural Steel for Buildings (A 9 – 21).
For Rivet Steel for Ships (A 13 – 21).
For Wrought Carbon-Steel Wheels for Electric Railway Service (A 25 – 23).
For Wrought Solid Carbon-Steel Wheels for Steam Railway Service (A 57 – 23).
For Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service (A 52 – 18).
For Cold-Drawn Bessemer Steel Automatic Screw Stock (A 32 – 14).

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, pp. 981 ff. (1922).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, pp. 951 ff. (1923).

For Cold-Drawn Open-Hearth Steel Automatic Screw Stock (A 54 - 15).

For Commercial Bar Steels (A 80 - 21).

II. Proposed Revisions in Tentative Standards.—(*a*) The committee recommends that the revisions in the following tentative standards, which appear in the Appendix to this report, be approved, and that the specifications as amended be advanced to standard:

For Steel Castings (A 27 - 23 T).

For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 22 T).

For Boiler and Firebox Steel for Stationary Service (A 70 - 23 T).

Methods of Chemical Analysis of Plain Carbon Steels (A 33 - 22 T).

Methods of Chemical Analysis of Alloy Steels (A 55 - 22 T).

(*b*) The committee recommend that the revisions in the following tentative specifications, which appear in the Appendix to this report, be approved, and that the specification as amended be continued as tenative:

For Carbon Tool Steel (A 71 - 21 T) with recommended practice for heat treatment.

III. Proposed New Tentative Standard.—The committee recommends that the following new tentative standard, which is appended to this report,[1] be accepted for publication as tentative:

Specifications for High-Speed Tool Steel, with recommended practice for heat treatment.

IV. Tentative Standards.—The committee recommends that the following tentative standards remain tentative for another year:

For Steel Tie Plates (A 67 - 20 T).

For Low-Carbon-Steel Track Bolts (A 76 - 20 T).

For Electric Cast-Steel Anchor Chain (A 77 - 20 T).

For Cold-Drawn Steel Wire for Concrete Reinforcement (A 82 - 21 T).

For Steel Plates of Structural Quality for Forge Welding (A 78 - 23 T).

For Carbon-Steel Castings for Railroads (A 87 - 22 T).

For Steel Plates of Flange Quality for Forge Welding (A 89 - 23 T).

The above recommendations have been referred to letter ballot vote of the committee, which consists of 165 members; 120 ballots have been cast; 45 members have refrained from voting. The analysis of the vote of the committee is given in Table I.

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[1] See p. 771.—ED.

TABLE I.—ANALYSIS OF VOTE ON RECOMMENDATIONS IN REPORT OF COMMITTEE A-1.

Items	Affirmative	Negative	Not Voting[a]
I. PROPOSED REVISIONS IN STANDARDS			
1. For Carbon-Steel Rails (A 1 – 14)	60	2	58
2. For Open-Hearth Steel Girder and High Tee Rails (A 2 – 21)	59	2	59
3. For Low-Carbon-Steel Splice Bars (A 3 – 14)	56	0	64
4. For Quenched Carbon-Steel Track Bolts (A 50 – 21)	59	1	60
5. For Structural Steel for Bridges (A 7 – 21)	70	0	50
6. For Structural Nickel Steel (A 8 – 21)	67	0	53
7. For Structural Steel for Buildings (A 9 – 21)	70	0	50
8. For Structural Steel for Locomotives (A 10 – 21)	71	2	47
9. For Structural Steel for Cars (A 11 – 21)	73	2	45
10. For Rivet Steel for Ships (A 13 – 21)	56	2	62
11. For Wrought Carbon-Steel Wheels for Electric Railway Service (A 25 – 23)	48	1	71
12. For Wrought Solid Carbon-Steel Wheels for Steam Railway Service (A 57 – 23)	57	2	61
*13. For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 21)	57	2	61
*14. For Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service (A 52 – 18)	60	1	59
15. For Welded and Seamless Steel Pipe (A 53 – 21)	58	1	61
16. For Automobile Carbon and Alloy Steels (A 29 – 21)	71	0	49
17. For Boiler Rivet Steel (A 31 – 21)	69	2	49
18. For Cold-Drawn Bessemer Steel Automatic Screw Stock (A 32 – 14)	63	1	56
19. For Cold-Drawn Open-Hearth Steel Automatic Screw Stock (A 54 – 15)	65	0	55
20. For Commercial Bar Steels (A 80 – 21)	73	2	45
II. PROPOSED REVISIONS IN TENTATIVE STANDARDS			
21. For Steel Castings (A 27 – 23 T)	77	1	42
22. For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 22 T)	60	3	57
23. For Boiler and Firebox Steel for Stationary Service (A 70 – 23 T)	63	3	54
24. For Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 22 T)	86	0	34
25. For Methods of Chemical Analysis of Alloy Steels (A 55 – 22 T)	82	0	38
26. For Carbon Tool Steel (A 71 – 21 T) with recommended practice for heat treatment	75	0	45
III. PROPOSED NEW TENTATIVE STANDARDS			
27. For High-Speed Tool Steel, with recommended practice for heat treatment	66	0	54

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* In case Specifications A 83 – 22 T are advanced to standard, Specifications A 28 – 21 and A 52 – 18 will be superseded by Specifications A 83.

[a] In this column is recorded the number of votes cast as "Not Voting" on the various items.

Total number of ballots cast	120
Number of members who failed to vote	45
Total membership	165

Submission of Specifications to the American Engineering Standards Committee.—In accordance with action taken at the meeting held on March 14, 1924, the following specifications have been approved for submission to the Secretary-Treasurer for transmission to the American Engineering Standards Committee:

For Low-Carbon-Steel Splice Bars (A 3 – 14).
For Medium-Carbon-Steel Splice Bars (A 4 – 14).
For High-Carbon-Steel Splice Bars (A 5 – 14).
For Extra-High-Carbon-Steel Splice Bars (A 6 – 14).
For Quenched High-Carbon-Steel Splice Bars (A 49 – 21).
For Quenched Carbon-Steel Track Bolts (A 50 – 21).
For Quenched Alloy-Steel Track Bolts (A 51 – 21).
For Steel Track Spikes (A 65 – 18).
For Steel Screw Spikes (A 66 – 21).

Specifications for Iron and Steel Chain (A 56 – 21 T).—Committee A-2 on Wrought Iron has made an extensive revision of these specifications and is recommending that the revision be approved for advancement to standard. Committee A-1 concurs in this recommendation.

Recommended Practice for Heat Treatment of Steel Castings.—Committee A-4 on Heat Treatment of Iron and Steel had made an extensive revision of this standard and is recommending that the revision be approved for advancement to standard. Committee A-1 concurs in this recommendation.

Election of Officers.—In accordance with the Regulations, the committee has held an election and chosen the following officers:

Chairman, F. M WARING
Vice-Chairmen, { J. B. YOUNG / C. F. W. RYS }
Secretary, G. H. WOODROFFE

The sub-committees of Committee A-1 also have held elections for chairmen.

In the following, the committee presents the foregoing recommendations in detail where necessary, as well as other features of its work, grouped for convenience in the order of the respective sub-committees responsible for them:

STEEL RAILS AND ACCESSORIES (SUB-COMMITTEE I)

This sub-committee has made certain changes in the Standard Specifications for Open-Hearth Girder Rails (A 2 – 21) in order to harmonize them with the American Electric Railway Engineering Association specifications. Ladle test requirements of Specifications for Low-Carbon-Steel Splice Bars (A 3 – 14) and Quenched Carbon-Steel Track Bolts (A 50 – 21) have been changed to agree with the Specifications for Low-Carbon-Steel Track Bolts (A 76 – 20 T), so that the requirements may be uniform in the three specifications; and provide for average determinations of manganese, phosphorus and sulfur in the case of bessemer melts over a twelve-hour period.

STRUCTURAL STEEL FOR BRIDGES, BUILDINGS AND ROLLING STOCK (SUB-COMMITTEE II)

This sub-committee has made extensive revisions of the specifications under its charge for the purpose of clarifying certain sections and bringing the specifications into line with present practice. It has been acting in cooperation with the American Railway Engineering Association committee and has accomplished considerable work in harmonizing specifications.

STRUCTURAL STEEL FOR SHIPS (SUB-COMMITTEE III)

This sub-committee reports progress in the preparation of specifications for marine boiler plates.

ROLLED STEEL WHEELS AND STEEL TIRES (SUB-COMMITTEE VII)

This sub-committee has presented revisions of the Specifications for Wrought Solid Carbon-Steel Wheels for Electric Railway Service (A 25 – 23), which have been harmonized with the specifications of the American Electric Railway Engineering Association; and revisions of the Specifications for Wrought Solid Carbon-Steel Wheels for Steam Railway Service (A 57 – 23), which have been harmonized with the American Railway Association specifications.

STEEL CASTINGS (SUB-COMMITTEE VIII)

This sub-committee has made a revision of the heat treatment clauses in the Tentative Specifications for Steel Castings (A 27 – 23 T) for the purpose of clarifying the meaning of the processes mentioned and definitely prohibiting the offering of any castings quenched in a liquid medium.

STEEL TUBING AND PIPE (SUB-COMMITTEE IX)

This sub-committee has made revisions of Specifications for Welded and Seamless Steel Pipe (A 53 – 21) principally in order to take care of double-extra-strong pipe. Also certain changes have been suggested in the Specifications for Boiler Tubes for Locomotives (A 28 – 21) and for Stationary Service (A 52 – 18) which specifications, however, are to be made obsolete should the Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 22 T) be made standard with all the revisions proposed at this time. The committee reports progress in the preparation of specifications for oil country tubular goods.

BOILER STEEL (SUB-COMMITTEE XI)

This sub-committee is recommending the addition of a tensile test to be taken longitudinally at the top end of firebox plates in Specifications for Boiler and Firebox Steel for Stationary Service (A 70 – 23 T). These revisions have been agreed upon with the Boiler Code Committee of the American Society for Mechanical Engineers.

METHODS OF CHEMICAL ANALYSIS (SUB-COMMITTEE XII)

This sub-committee has made a number of changes, principally in form, in Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 22 T) and Methods of Chemical Analysis of Alloy Steels (A 55 – 22 T).

TOOL STEEL (SUB-COMMITTEE XIV)

This sub-committee has revised the Specifications for Carbon Tool Steels (A 71 – 21 T) and is submitting a new Tentative Specification for High-Speed Tool Steel. It has also obtained from the American Society for Steel Treating certain tentative recommended methods of heat treatment for carbon and high-speed steel, which are included as an appendix to the specifications.

COMMERCIAL BAR STEELS (SUB-COMMITTEE XV)

This sub-committee is recommending a change in title of Specifications for Cold-Drawn Bessemer Steel Automatic Screw Stock (A 32 – 14) and Specifications for Cold-Drawn Open-Hearth Steel Automatic Screw Stock (A 54 – 15); and also a change in permissible variations of diameter for bars up to 0.3 in. which applies to Specifications for Commercial Bar Steels (A 80 – 21) as well.

SHEET STEELS (SUB-COMMITTEE XIX)

This sub-committee reports progress in the work of its various sub-committees on cold-rolled strip steel and automobile sheet steel.

This report has been submitted to letter ballot of the committee, which consists of 165 members, of whom 118 have voted affirmatively, none negatively, and 47 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. M. WARING,
Chairman.

G. H. WOODROFFE,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Steel Track Spikes, proposed in 1922, and of the Standard Specifications for Boiler and Firebox Steel for Locomotives, proposed in 1923, referred to in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The revisions of the Standard Specifications for Lap-Welded and Seamless Steel Boiler Tubes for Locomotives, for Welded and Seamless Steel Pipe, for Automobile Carbon and Alloy Steels, for Open-hearth Steel Girder and High Tee Rails, for Steel Castings, for Boiler Rivet Steel and of the Standard Methods of Chemical Analysis of Plain Carbon Steel and of Chemical Analysis of Alloy Steels, proposed either in 1922 or 1923, and as further amended as given in the appendix to this report, were approved as recommended in the report and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Specifications for Structural

Nickel Steel, for Structural Steel for Locomotives and for Structural Steel for Cars, proposed in 1922, and subsequently amended in 1923 and as further amended as given in the appendix to this report, were approved at the annual meeting, with the exception noted on page 31 of the Summary of Proceedings, and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Specifications for Carbon Steel Rails, for Low-Carbon-Steel Splice Bars, for Quenched Carbon-Steel Track Bolts, for Rivet Steel for Ships, for Wrought Solid Carbon-Steel Wheels for Steam Railway Service, for Wrought Carbon-Steel Wheels for Electric Railway Service, for Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service, for Cold-Drawn Bessemer Steel Automatic Screw Stock, for Cold-Drawn Open-hearth Steel Automatic Screw Stock and for Commercial Bar Steels, proposed for the first time in 1924, as given in the appendix to this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Specifications for Structural Steel for Bridges and for Structural Steel for Buildings, proposed in 1924, as given in the appendix to this report, with the exceptions noted on page 30 of the Summary of Proceedings, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes and for Boiler and Firebox Steel for Stationary Service, amended as given in the appendix to this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924, and appear in the 1924 Book of A.S.T.M. Standards. The former specifications supersede the Standard Specifications for Lap-Welded and Seamless Steel Boiler Tubes for Locomotives and for Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service. These specifications were accordingly withdrawn.

The proposed revisions of the Tentative Specifications for Carbon Tool Steel, referred to in this report, were accepted. The specifications, as thus revised, appear on page 765.

The proposed Tentative Specifications for High-Speed Tool Steel, referred to in this report, were accepted for publication as tentative and appear on page 771.

APPENDIX

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR STEEL

In this appendix are given proposed revisions in certain standard and tentative specifications, which, for convenience, are numbered from 1 to 26, inclusive, to correspond to the report of the committee. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

PROPOSED REVISIONS IN STANDARDS

No. 1.—STANDARD SPECIFICATIONS FOR CARBON-STEEL RAILS: A 1 - 14[1]

Section 17.—In paragraphs (*b*), (*c*) and (*d*) insert the words "of the three" between the words "any" and "test," making these read "the appearance of the fracture of any *of the three* test pieces representing, etc."

No. 2.—STANDARD SPECIFICATIONS FOR OPEN-HEARTH STEEL GIRDER AND HIGH TEE RAILS: A 2 - 21[1]

Title.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> "Specifications for *the Manufacture of* Open-Hearth Steel Girder [and High Tee] Rails *of Plain, Grooved and Guard Types.*"

No. 3.—STANDARD SPECIFICATIONS FOR LOW-CARBON-STEEL SPLICE BARS: A 3 - 14[1]

Section 3.—Change to read as follows:

> "(*a*) A carbon determination shall be made of each melt of bessemer steel, and two analyses every 24 hours representing the average of the elements carbon, manganese, phosphorus and sulfur contained in the steel, one for each 12-hour period, respectively. These analyses shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.
>
> "(*b*) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2."

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[1] 1921 Book of A.S.T.M. Standards.

NO. 4.—STANDARD SPECIFICATIONS FOR QUENCHED CARBON-STEEL TRACK BOLTS: A 50 - 21[1]

Section 4.—Change to read as follows:

"(*a*) A carbon determination shall be made of each melt of bessemer steel, and two analyses every 24 hours representing the average of the elements carbon, manganese, phosphorus and sulfur contained in the steel, one for each 12-hour period, respectively. These analyses shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

"(*b*) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3."

NO. 5.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES: A 7 - 21[1]

Section 6 (*a*).—Add to the table of physical properties, the following yield point requirements:

"but in no case less than 30,000 lb. per sq. in. and 25,000 lb. per sq. in. for structural steel and rivet steel, respectively."

Section 8.—In the first line of Paragraph (*a*) omit the words, "for plates, shapes and bars."

In the second line omit the reference to Paragraph (*d*).

Omit Paragraph (*c*) reading as follows, relettering the subsequent paragraph accordingly:

"The 1 by ½-in. test specimen for pins, rollers and other bars, when prepared as specified in Section 9, shall bend cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion."

Section 9.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

"(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

"(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

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[1] 1921 Book of A.S.T.M. Standards.

"(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel. Bend test specimens for eyebar flats may have three rolled sides.

"(*f*) Tension test specimens for material over 1½ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

"(*g*) Bend test specimens for material over 1½ in. in thickness or diameter, except eyebar flats, pins, and rollers, may be machined to a thickness or diameter of at least ¾ in. or to 1 by ½ in. in section.

"(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by ½ in. in section.

"(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

"(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

Table I.—Change the title to read as follows:

"Permissible Variations of Rectangular Plates Ordered to Weight."

Table II.—Change the title to read as follows:

"Permissible Overweights of Rectangular Plates Ordered to Thickness."

Add the following note under Table II:[1]

"NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

NO. 6.—STANDARD SPECIFICATIONS FOR STRUCTURAL NICKEL STEEL: A 8 - 21[2]

Section 9.—In the first sentence of Paragraph (*a*), omit the phrase "for plates, shapes and bars."

Omit Paragraph (*b*) reading as follows, relettering the subsequent paragraph accordingly, since this requirement is covered in Paragraph (*a*):

"The test specimen for pins and rollers shall bend cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion."

Section 11.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

"(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

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[1] This revision was not accepted at the annual meeting; see Summary of Proceedings, p. 30.—ED.

[2] 1921 Book of A.S.T.M. Standards.

"(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

"(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel. Bend test specimens for eyebar flats may have three rolled sides.

"(*f*) Tension test specimens for material over 1½ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

"(*g*) Bend test specimens for material over 1½ in. in thickness or diameter, except eyebar flats, pins, and rollers, may be machined to a thickness or diameter of at least ¾ in. or to 1 by ½ in. in section.

"(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by ½ in. in section.

"(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

"(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

Table I.—Change the title to read as follows:

"Permissible Variations of Rectangular Plates Ordered to Weight."

Table II.—Change the title to read as follows:

"Permissible Overweights of Rectangular Plates Ordered to Thickness."

Add the following note under Table II:[1]

"NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

NO. 7.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BUILDINGS: A 9 – 21[2]

Section 3.—Change to read as follows:

"(*a*) A carbon determination shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 12-hour period.

"(*b*) An analysis of each melt of open-hearth steel shall be made for carbon, manganese, phosphorus and sulfur.

"(*c*) These analyses shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 2."

Section 5.—Add to the table of physical properties a yield point requirement as follows:

"but in no case less than 30,000 lb. per sq. in. and 25,000 lb. per sq. in. for structural steel and rivet steel, respectively."

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[1] This revision was not accepted at the annual meeting; see Summary of Proceedings, p. 31.—ED.

[2] 1921 Book of A.S.T.M. Standards.

Section 7.—In the first line of Paragraph (*a*), omit the words, "for plates, shapes and bars."

In the second line, omit reference to Paragraph (*c*).

Omit Paragraph (*b*) reading as follows, relettering the subsequent paragraph accordingly:

"The 1 by ½-in. test specimen for pins, rollers and other bars, when prepared as specified in Section 8, shall withstand being bent cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion."

Section 8.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

"(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

"(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

"(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

"(*f*) Tension test specimens for material over 1½ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

"(*g*) Bend test specimens for material over 1½ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least ¾ in. or to 1 by ½ in. in section.

"(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by ½ in. in section.

"(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

"(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

Table I.—Change the title to read as follows:

"Permissible Variations of Rectangular Plates Ordered to Weight."

Table II.—Change the title to read as follows:

"Permissible Overweights of Rectangular Plates Ordered to Thickness."

Add the following note under Table II:[1]

"NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

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[1] This revision was not accepted at the annual meeting; see Summary of Proceedings, p. 30.—ED.

NO. 8.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR LOCOMOTIVES: A 10 - 21[1]

Section 6.—Change the first sentence of Paragraph (*a*) to read as follows by the addition of the italicized words:

"The material, *except as specified in Paragraph* (*c*), shall conform to the following requirements as to tensile properties."

Change Paragraph (*c*) to read as follows by the addition of the italicized words and the omission of the word in brackets:

"Plates $\frac{3}{16}$ in. or under in thickness, *shapes less than 1 sq. in. in section, and bars less than* $\frac{1}{2}$ *sq. in. in section need* [shall] not be subjected to tension tests."

Section 9.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or section of material as rolled.

"(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

"(*d*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

"(*e*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

"(*f*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius of not over $\frac{1}{16}$ in."

Section 10.—Omit the last sentence of Paragraph (*a*) reading as follows:

"Shapes less than 1 sq. in. in section and bars less than $\frac{1}{2}$ sq. in. in section need not be subjected to a tension test."

Change Paragraph (*c*) to read as follows by the addition of the italicized words:

"If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is *more than* $\frac{3}{4}$ *in. from the center of the gage length of a 2-in. specimen or is* outside the middle third of the gage length *of an 8-in. specimen* as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed."

Table I.—Change the title to read as follows:

"Permissible Variations of Rectangular Plates Ordered to Weight."

Table II.—Change the title to read as follows:

"Permissible Overweights of Rectangular Plates Ordered to Thickness."

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[1] 1921 Book of A.S.T.M. Standards.

Add the following note under Table II:[1]

"NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

NO. 9.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR CARS: A 11 - 21[2]

Section 3.—Add a Paragraph (*b*) to read as follows:

"(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper.......................... not less than 0.20 per cent"

Section 4.—Change the first sentence to read as follows by the addition of the italicized words:

"An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur, *and also copper when copper steel is specified.*"

Section 6 (*c*).—Change to read as follows by the addition of the italicized words:

"Plates $\frac{3}{16}$ in. or under in thickness, *shapes less than 1 sq. in. in section, and bars, except rivet rods, less than $\frac{1}{2}$ in. in section need* [shall] not be subjected to tension tests."

Section 9.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

"(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

"(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*) and (*g*), shall be of the full thickness or section of material as rolled.

"(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

"(*f*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

"(*g*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in in section.

"(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

Section 10.—Omit the last sentence of Paragraph (*a*) reading as follows:

"Shapes less than 1 sq. in. in section, and bars, except rivet rods, less than $\frac{1}{2}$ in. in section, need not be subjected to a tension test."

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[1] This revision was not accepted at the annual meeting; see Summary of Proceedings, p. 31.—ED.

[2] 1921 Book of A.S.T.M. Standards.

Change Paragraph (*c*) to read as follows by the addition of the italicized words:

"If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is *more than* $\frac{3}{4}$ *in. from the center of the gage length of a 2-in. specimen or is* outside the middle third of the gage length *of an 8-in. specimen* as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed."

Table I.—Change the title to read as follows:

"Permissible Variations of Rectangular Plates Ordered to Weight."

Table II.—Change the title to read as follows:

"Permissible Overweights of Rectangular Plates Ordered to Thickness."

Add the following note under Table II:[1]

"NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table."

NO. 10.—STANDARD SPECIFICATIONS FOR RIVET STEEL FOR SHIPS: A 13 – 21[2]

Sections 16 and 17.—Omit these sections, reading as follows, renumbering the subsequent sections accordingly:

"16. A copy of the results of tension tests of the rolled bars from which the rivets were made shall be furnished for each lot of rivets.

"17. If the test certificate required in Section 16 cannot be furnished, the rivets shall conform to the requirements as to tensile properties specified in Sections 5 and 6, except that the elongation shall be measured on a gage length as great as the length of the rivets tested will permit."

Section 20.—Omit Paragraph (*a*) reading as follows, relettering the subsequent paragraph accordingly:

"When required in accordance with Section 17, one tension test shall be made from each size in each lot of rivets offered for inspection."

Add a new Section 19 to be substituted in place of the present Sections 21 and 22, to read as follows:

"19. *Workmanship and Finish.*—The rivets shall be true to form and concentric, shall be made in a workmanlike manner and shall be free from injurious defects."

Renumber the present Sections 23 and 24 to read 20 and 21, respectively.

NO. 11.—STANDARD SPECIFICATIONS FOR WROUGHT CARBON-STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE: A 25 – 16[2]

These specifications have been extensively revised and are appended hereto[3] in their proposed revised form.

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[1] This revision was not accepted at the annual meeting; see Summary of Proceedings, p. 31.—ED.

[2] 1921 Book of A.S.T.M. Standards.

[3] See 1924 Book of A.S.T.M. Standards.—ED.

NO. 12.—STANDARD SPECIFICATIONS FOR WROUGHT SOLID CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE: A 57 – 16[1]

These specifications have been extensively revised and are appended hereto[2] in their proposed revised form.

NO. 13.—STANDARD SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR LOCOMOTIVES: A 28 – 21[1]

Section 8.—Change the value of the factor D in the formula to equal the outside diameter instead of the inside diameter.

NO. 14.—STANDARD SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL AND WROUGHT-IRON BOILER TUBES FOR STATIONARY SERVICE: A 52 – 18[1]

Section 7.—Change the value of the factor D in the formula to equal the outside diameter instead of the inside diameter.

Section 8.—Change the requirements for etching solutions as given in the footnote to this section to conform to the following:

"(*a*)	Hydrochloric acid (sp. gr. 1.19)	10 per cent
	Sulfuric acid (sp. gr. 1.84)	30 "
	Water	60 "
or		
"(*b*)	Nitric acid (sp. gr. 1.42)	25 per cent
	Water	75 "

NO. 15.—STANDARD SPECIFICATIONS FOR WELDED AND SEAMLESS STEEL PIPE: A 53 – 21[1]

Section 1.—Change to read as follows by the addition of the italicized words:

"These specifications cover 'standard,' 'extra strong,' and '*double extra strong*' welded and seamless steel pipe. Pipe ordered under these specifications is intended for bending, flanging and other special purposes."

Section 4.—Add a new column in the table of requirements to cover requirements for medium-carbon steel for seamless pipe and change the elongation requirement for low-carbon seamless pipe to 40 per cent in 2 in.

The physical requirements for seamless steel pipe will then be as follows, the requirements for welded pipe to remain without change.

	SEAMLESS	
	OPEN-HEARTH LOW CARBON	OPEN-HEARTH MEDIUM CARBON
Tensile strength, lb. per sq. in.	48 000	62 000
Yield point, lb. per sq. in.	26 500	35 000
Elongation in 2 in., per cent	40	25

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[1] 1921 Book of A.S.T.M. Standards.

[2] See 1924 Book of A.S.T.M. Standards.—ED.

Section 5.—Omit Paragraph (*b*), and in Paragraph (*a*) omit the word "Welded," Section 5 to then read:

"Pipe shall be tested at the mill to the hydrostatic pressures specified in Table I."

Table I.—Change the title to read as follows by the addition of the italicized words:

"Hydrostatic Pressures for Welded *and Seamless* Steel Pipe."

Add a column at the right of Table I which shall give the test pressure for Double Extra Strong Pipe, making this table agree with the accompanying Table I.

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED AND SEAMLESS STEEL PIPE.
(Pressures Expressed in Pounds per Square Inch.)

Size (Nominal Inside Diameter), in.	"Standard" Pipe			"Extra Strong" Pipe			"Double Extra Strong" Pipe	
	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Butt-weld	Lap-weld and Seamless	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-weld	Lap-weld and Seamless	Butt-weld	Lap-weld and Seamless
⅛.......	....	700	....	....	700	....	....	....
¼.......	....	700	....	....	700	....	....	....
⅜......	....	700	....	....	700	....	....	....
½.......	....	700	....	....	700	....	700	....
¾.......	....	700	....	....	700	....	700	....
1.......	....	700	....	....	700	....	700	....
1¼.......	....	700	1000	....	1500	2500	2200	....
1½.......	....	700	1000	....	1500	2500	2200	3000
2........	....	700	1000	....	1500	2500	2200	3000
2½.......	....	800	1000	....	1500	2000	2200	3000
3........	....	800	1000	....	1500	2000	2200	3000
3½.......	....	...	1000	....	....	2000	....	2500
4........	....	...	1000	....	....	2000	....	2500
4½.......	....	...	1000	....	....	1800	....	2000
5........	....	...	1000	....	....	1800	....	2000
6........	....	...	1000	....	....	1800	....	2000
7........	....	...	1000	....	....	1500	....	2000
8........	25.00	...	800	....	....	....	....	2000
8........	28.81	...	1000	43.39	....	1200	....	....
9........	34.19	...	900	48.73	....	1200	....	....
10........	32.00	...	600	....	....	....	....	....
10........	35.00	...	700	....	....	....	....	....
10........	41.13	...	900	54.74	....	1000	....	....
11........	46.25	...	800	60.08	....	1000	....	....
12........	45.00	...	600	....	....	....	....	....
12........	50.71	...	800	65.42	....	1000	....	....

For pipes over 12 in. in inside diameter, the test pressures should be calculated by the formula $P = \frac{2\,St}{D}$ in which P = pressure in pounds per sq. inch; S = fiber stress, 12,000 lb. per sq. in.; t = thickness of wall in inches; D = outside diameter in inches.

Section 6.—Add a new Paragraph (*c*) to read as follows:

"(*c*) The flattening test will not be required on double extra strong pipe."

Section 7.—Add a sentence to read as follows:

"This test will not be required on double extra strong pipe over 1¼ in. in diameter."

Table II.—Add a column at the right of Table II giving the thickness and weight of pipe per linear foot for double extra strong pipe up to 8 in. in size, inclusive, making this table agree with the accompanying Table II.

TABLE II.—STANDARD WEIGHTS AND DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE.

Size (Nominal Inside Diameter), in.	Outside Diameter, in.	"Standard" Pipe			"Extra Strong" Pipe		"Double Extra Strong" Pipe	
		Number of Threads per Inch	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.
⅛.......	0.405	27	0.068	0.25	0.095	0.31	....	....
¼.......	0.540	18	0.088	0.43	0.119	0.54	....	....
⅜.......	0.675	18	0.091	0.57	0.126	0.74	....	....
½.......	0.840	14	0.109	0.85	0.147	1.09	0.294	1.71
¾.......	1.050	14	0.113	1.13	0.154	1.47	0.308	2.44
1........	1.315	11½	0.133	1.68	0.179	2.17	0.358	3.66
1¼.......	1.660	11½	0.140	2.28	0.191	3.00	0.382	5.21
1½......	1.900	11½	0.145	2.73	0.200	3.63	0.400	6.41
2.......	2.375	11½	0.154	3.68	0.218	5.02	0.436	9.03
2½......	2.875	8	0.203	5.82	0.276	7.66	0.552	13.70
3.......	3.500	8	0.216	7.62	0.300	10.25	0.600	18.583
3½......	4.000	8	0.226	9.20	0.318	12.51	0.636	22.85
4.......	4.500	8	0.237	10.89	0.337	14.98	0.674	27.54
4½......	5.000	8	0.247	12.64	0.355	17.61	0.710	32.53
5.......	5.563	8	0.258	14.81	0.375	20.78	0.750	38.55
6.......	6.625	8	0.280	19.19	0.432	28.57	0.864	53.16
7.......	7.625	8	0.301	23.77	0.500	38.05	0.875	63.08
8*......	8.625	8	0.277	25.00	....	....	0.875	72.42
8.......	8.625	8	0.322	28.81	0.500	43.39	....	....
9.......	9.625	8	0.342	34.19	0.500	48.73	....	....
10*......	10.750	8	0.279	32.00	....	....	....	....
10*......	10.750	8	0.307	35.00	....	....	....	....
10.......	10.750	8	0.365	41.13	0.500	54.74	....	....
11.......	11.750	8	0.375	46.25	0.500	60.08	....	....
12*......	12.750	8	0.330	45.00	....	....	....	....
12.......	12.750	8	0.375	50.71	0.500	65.42	....	....

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the table are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than those shown in the table are measured by the outside diameter and will be furnished with plain ends unless otherwise specified; for such sizes it will be necessary to accept Manufacturers' weights or calculate the weights on the basis of one cubic inch of steel weighing 0.2833 lb.

Section 12.—Change to read as follows by the addition of the italicized words:

"The weight of the pipe shall not vary more than 5 per cent *for standard and extra strong pipe nor more than 10 per cent for double extra strong pipe* from that specified in Table II."

Section 13 (b).—Change to read as follows by the addition of the italicized words:

"Extra strong *and double extra strong* pipe shall be in random lengths of 12 to 22 ft. Five per cent may be in lengths of 6 to 12 ft."

Section 15 (b).—Change to read as follows by the addition of the italicized words:

"Extra strong welded pipe and standard and extra strong seamless pipe *and all double extra strong pipe* shall be furnished with plain ends."

No. 16.—Standard Specifications for Automobile Carbon and Alloy Steels: A 29 – 21[1]

Change the word "Automobile" to read "Automotive" in the title and text of the specifications.

No. 17.—Standard Specifications for Boiler Rivet Steel: A 31 – 21[1]

Insert a new Sub-Title "IX. Permissible Variations in Diameter," and new Sections 20 and 21 as follows, renumbering the subsequent sections accordingly:

"IX. Permissible Variations in Diameter

"20. *Permissible Variations.*—The diameter of finished rivets, measured cold, shall not vary from that specified more than the amounts given in the following table:

Diameter, in.	Variations in Diameter, in. Snap Gage Measurement	Variations in Diameter, in. Ring Gage Measurement
Up to $\frac{1}{2}$, inclusive	0.022 under	0.020 over
Over $\frac{1}{2}$ to 1, inclusive	0.025 "	0.030 "
Over 1 to $1\frac{1}{4}$, inclusive	0.027 "	0.035 "
Over $1\frac{1}{4}$ to $1\frac{1}{2}$, inclusive	0.030 "	0.040 "
Over $1\frac{1}{2}$ to 2, inclusive	0.037 "	0.040 "

"Snap gage measurement shall be made at the point of minimum diameter, but it is not required that the rivet shall turn completely in the gage. Measurements of the maximum tolerance shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

"21. The dimensions of the rivet head shall not vary from that specified more than the amounts given in the following table:

Ordered Diameter of Rivets, in.	Head Tolerances, in. Width				Head Tolerances, in. Height
$\frac{1}{2}$	plus	$\frac{1}{16}$	minus	$\frac{1}{32}$	plus $\frac{1}{32}$
$\frac{9}{16}$	"	$\frac{1}{16}$	"	$\frac{1}{32}$	" $\frac{1}{32}$
$\frac{5}{8}$	"	$\frac{1}{16}$	"	$\frac{1}{32}$	" $\frac{1}{32}$
$\frac{11}{16}$	"	$\frac{1}{16}$	"	$\frac{1}{32}$	" $\frac{1}{32}$
$\frac{3}{4}$	"	$\frac{5}{64}$	"	$\frac{1}{32}$	" $\frac{1}{32}$
$\frac{7}{8}$	"	$\frac{5}{64}$	"	$\frac{1}{32}$	" $\frac{1}{32}$
1	"	$\frac{5}{64}$	"	$\frac{1}{32}$	" $\frac{1}{32}$

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[1] 1921 Book of A.S.T.M. Standards.

No. 18.—STANDARD SPECIFICATIONS FOR COLD-DRAWN BESSEMER STEEL AUTOMATIC SCREW STOCK: A 32 - 14[1]

Title.—Change the word "Cold-Drawn" to read "Cold-Finished."

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

"2. The steel shall be made by the bessemer process, and shall be cold-rolled [or cold-drawn or turned to size], *cold-drawn, turned and polished, or turned and ground.*"

Section 5.—In the table of permissible variations, transpose the columns for oversize and undersize; also change the variations for sizes up to and including 0.3 in. to read 0.002 in. under, 0 over, eccentricity, 0.001 in.

No. 19.—STANDARD SPECIFICATIONS FOR COLD-DRAWN OPEN-HEARTH STEEL AUTOMATIC SCREW STOCK: A 54 - 15[1]

Title.—Change the word "Cold-Drawn" to read "Cold-Finished."

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

"The steel shall be made by the open-hearth process, and shall be cold-rolled [or cold-drawn or turned to size], *cold-drawn, turned and polished, or turned and ground.*"

Section 5.—In the table of permissible variations, transpose the columns for oversize and undersize; also change the variations for sizes up to and including 0.3 in. to read 0.002 in. under, 0 over, eccentricity, 0.001 in.

No. 20.—STANDARD SPECIFICATIONS FOR COMMERCIAL BAR STEELS A 80 - 21[1]

Table III.—Under cold-finished bars, change the variation for rounds and hexagons up to 0.3 in. to read 0.002 in. instead of 1 per cent of diameter.

PROPOSED REVISIONS IN TENTATIVE STANDARDS

No. 21.—TENTATIVE SPECIFICATIONS FOR STEEL CASTINGS: A 27 - 23 T[2]

Section 3.—Change from its present form: namely,

"(*a*) Class A castings need not receive any heat treatment unless so specified, or unless the carbon content exceeds 0.30 per cent.

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[1] 1921 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 555 (1923).

"(*b*) Class B castings shall receive a proper heat treatment, the treatment depending upon the design and chemical composition of the castings.

"(*c*) Heat treatment shall be in accordance with the Tentative Recommended Practice for Heat Treatment of Carbon-Steel Castings (Serial Designation: A 36 - 22 T), of the American Society for Testing Materials, unless otherwise specified by the purchaser."

to read as follows:

"(*a*) Class A castings need not receive any heat treatment unless so specified, or unless the carbon content exceeds 0.30 per cent.

"(*b*) Class B castings and Class A castings in which the carbon content is over 0.30 per cent, shall receive a heat treatment proper to the design and chemical composition of the castings.

"(*c*) Heat treatment, unless otherwise specified by the purchaser, may consist of annealing, or of normalizing, or of normalizing followed by annealing, or of normalizing followed by a draw-back to a temperature below the critical range. No castings which have been quenched in any liquid medium shall be offered under this specification.

"(*d*) *Annealing.*—The procedure for annealing shall consist in allowing the castings to cool after pouring, to a temperature below the critical range. They shall then be uniformly reheated to the proper temperature to refine the grain, and allowed to cool uniformly in the furnace.

"(*e*) *Normalizing.*—The procedure for normalizing shall consist in allowing the castings to cool after pouring to a temperature below the critical range. They shall then be reheated to the proper temperature to refine the grain and allowed to cool in still air."

Section 7.—Omit Paragraph (*b*) reading as follows, relettering the subsequent paragraph accordingly:

"No maximum limit shall be placed on the tensile strength in any of the grades."

Add a footnote to Paragraph (*a*), to read as follows:

"Because it has come to the attention of Committee A-1 on Steel that the intent of the requirement of Section 7 (*a*) has at times been misinterpreted, the committee wishes to make it clear that it is not intended that maximum limits shall be placed on the tensile strength in any of the grades specified."

No. 22.—Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes:

A 83 - 22 T[1]

Section 6 (*a*).—Change the last sentence to read as follows by the addition of the italicized words:

"For *iron and* steel tubes over $2\frac{1}{2}$ in. in diameter and up to $3\frac{3}{4}$ in., inclusive, the width of the flange shall be $\frac{3}{8}$ in., and for tubes over $3\frac{3}{4}$ in., the width of flange shall be 10 per cent of the outside diameter."

Section 8.—Revise the next to the last sentence by substituting "$1\frac{1}{2}$ in." for "$1\frac{3}{4}$ in." in the provision for the crushing test for iron tubes heavier than No. 10 B.w.g.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 553 (1922).

Section 9.—Change the value of the factor *D* in the formula to equal the outside diameter in inches, instead of the inside diameter.

Section 10.—Change the requirements for etching solutions as given in the footnote to this section to conform to the following:

"(*a*)	Hydrochloric acid (sp. gr. 1.19)	10 per cent
	Sulfuric acid (sp. gr. 1.84)	30 "
	Water	60 "
or		
"(*b*)	Nitric acid (sp. gr. 1.42)	25 per cent
	Water	75 "

No. 23.—TENTATIVE SPECIFICATIONS FOR BOILER AND FIREBOX STEEL FOR STATIONARY SERVICE: A 70 – 23 T[1]

Section 6.—Insert a new Paragraph (*b*) to read as follows, relettering paragraphs (*b*) and (*c*) accordingly:

"(*b*) Tensile strength only need be determined on the test specimen taken longitudinally from the top of firebox plates, and it shall not exceed 70,000 lb. per sq. in."

Section 10 (a).—Change to read as follows by the addition of the italicized words:

"Tension test specimens shall be taken longitudinally from the *top and* bottom *corners* of the finished rolled *firebox material and from the bottom only of flange* material. Bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot and the transverse test specimen at right angles to that axis."

Section 11 (a).—Change to read as follows by the addition of the italicized words:

"*Two tension and one bend test shall be made from each firebox steel plate as rolled.* One tension and one bend test shall be made from each *flange steel* plate as rolled."

No. 24.—TENTATIVE METHODS OF CHEMICAL ANALYSIS OF PLAIN CARBON STEELS: A 33 – 22 T[2]

Revise as follows, all page references referring to the *Proceedings* of the Society, Vol. 22, Part I (1922):[1]

Page 578.—Insert the following introductory paragraph:

"The following methods are subject to various errors which can not easily be overcome. Formulas which show the errors which are to be expected are therefore given under the general heading "Allowable Error" after the preferred method. These are fair estimates of the performance of the methods in different hands."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 541 (1923).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 578 (1922).

Page 579.—Add the following sentence to the paragraph headed "Oxygen":

> "The oxygen may be regulated either by means of a high pressure reducing valve or by means of a gasometer or gas holder."

Page 582.—Insert the following paragraph above "Notes":

> "*Allowable Error.*—Percentages of carbon determined by the above method should be accurate to ± [0.01 + (0.02 × the percentage of carbon found)]."

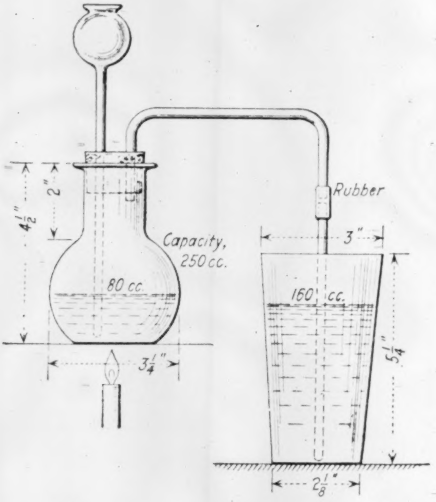

FIG. 1.

Page 588.—Insert the following paragraph above "Notes":

> "*Allowable Error.*—Percentages of manganese determined by the above method should be accurate to ± [0.01 + (0.02 × the percentage of manganese found)]."

Page 589.—In the paragraph on "Standard Sodium Arsenite" under "Solutions Required," change the words "as under Determination of Manganese by the Bismuthate Method," to read as follows:

> "Against a standard steel or by means of 5 cc. of standard 0.03 *N* permanganate solution which has been reduced and then carried through the steps of the method described below."

Page 589.—In the "Method," last line, omit "to a clear green color."

Page 591.—Insert the following paragraph above "Notes":

"*Allowable Error.*—Percentages of phosphorus determined by the above method should be accurate to ± [0.002 + (0.02 × the percentage of phosphorus found)]."

Page 593.—Under "Notes," change the third paragraph from its present form: namely,

"Bureau of Standards Standard Steel No. 19*a* or its renewal is recommended as a suitable steel for standardization of the sodium hydroxide solution."

to read as follows:

"Appropriate Bureau of Standards Standard Steels are recommended for the standardization of the sodium hydroxide solution."

Page 593.—Under "Notes," fourth paragraph, add the sentence:

"The ratio 23 molecules of sodium hydroxide to 1 atom of phosphorus represents the reaction very closely if the phosphomolybdate is precipitated at 35 to 45° C."

Page 594.—Change Fig. 3 to conform to the accompanying Fig. 1.

Page 595.—Insert the following paragraph above "Notes":

"*Allowable Error.*—Percentages of sulfur determined by the above method should be accurate to ± [0.002 + (0.02 × the percentage of sulfur found)]."

Page 595.—Under apparatus omit the sentence:

"Use a 500-cc. flask with a delivery tube and a 300-cc. tumbler of tall form (Fig. 3)."

and substitute:

"Fig. 3 shows a typical apparatus for this determination. A spray trap may be put in the outlet tube to prevent iron from passing over into the ammoniacal solution."

Page 595.—Under solutions required, insert as a third paragraph:

"*Ammoniacal Zinc Sulfate.*—Dissolve 20 g. of $ZnSO_4 \cdot 7H_2O$ in 1080 cc. of water and add 920 cc. of ammonium hydroxide (sp. gr. 0.90)".

Page 595.—Under Solutions Required, substitute the following after "Potassium Iodate":

"Dissolve 1.12 g. of KIO_3 and 12 g. of KI in 1000 cc. of distilled water. For general work the theoretical sulfur titre of this solution should be used; for specialized work on one kind of material, the solution may be standardized against like material. The theoretical titre is based on standard sodium oxalate and is obtained as follows: To 300 cc. of water in a 600-cc. flask, preferably glass stoppered, add 10 cc. of HCl (sp. gr. 1.19) and 1 g. of KI. Cool and add 25 cc. of 0.03 *N* $KMnO_4$ solution which has been standardized against sodium oxalate. Swirl gently, stopper, and let stand for five minutes. Titrate the liberated iodine with thiosulfate solution until the color fades. Then add 10 cc. of starch solution and continue the titration until the blue color is destroyed. Repeat the titration with the sole difference that 25 cc. of the iodate solution is substituted for the standard permanganate solution. Calculate the normality of the iodate solution, and dilute it if desired so that its normality is 0.0312 or 1 cc. is equivalent to 0.01 per cent of sulfur on a 5-g. sample. For standardization against like material, 5-g. portions of the proper standard steel are carried through all steps of the method."

Page 595.—Under Solutions Required, omit the present paragraph on "Starch" and substitute the following:

"*Starch Indicator.*—(1) To 1000 cc. of boiling distilled water, add a cold suspension of 6 g. of starch in 100 cc. of water and boil vigorously for five minutes. Cool the solution, add 6 g. of $ZnCl_2$ dissolved in 50 cc. of cold water, thoroughly mix and set aside for 24 hours. Decant the clear supernatant liquid into a suitable container, add 3 g. of KI and mix thoroughly. (2) (Optional). Prepare an emulsion of 6 g. of soluble starch in 25 cc. of water, add a solution of 1 g. of NaOH in 10 cc. of water, and stir the solution until it gelatinizes. Dilute to 1000 cc., add 3 g. of KI, and mix thoroughly."

Page 595.—In the "Method" after "cadmium chloride" insert "or zinc sulfate."

Page 595.—Under "Method," eighth line, change the sentence beginning "Add 5 cc. of starch," etc., to read as follows:

"Add 5 cc. of starch solution, then 40 cc. of dilute HCl (1:1) and titrate *immediately* with the potassium iodate solution to a permanent blue color."

Page 595.—In the "Method," omit the last sentence, reading as follows:

"When a blue color is first obtained, add 20 cc. of dilute HCl (1:1) and continue the titration to a permanent faint blue color."

Page 596. Notes.—Omit all present notes and substitute the following:

"This method succeeds best when the evolution of gas is rapid and the conditions are kept constant.

"Some analysts prefer to add the dilute HCl at a temperature of 80 to 90° C. and to heat the flask on an electric heater instead of over gas. The use of concentrated HCl necessitates a condensing arrangement and does not offer any general advantages over the diluted acid.

"With most plain carbon steel, the results for sulfur which are obtained by the evolution method and the use of the theoretical sulfur titre, check the gravimetric results within ±0.002 per cent. Some steels dissolve too slowly and some, as, for example, certain steels containing high sulfur and carbon, do not yield all of their sulfur. In such cases the samples must be annealed as follows:

"Transfer 5 g. of drillings to a 12.5-cm. filter paper, and wrap the sample securely in the paper so that at least three thicknesses of paper cover the steel. Place the package in a 25-cc. porcelain crucible, cover the crucible tightly so that no air can enter, and heat for 20 minutes at a bright red heat over a burner or preferably in a muffle. The filter paper should be charred but not burned. Cool and proceed as in the regular method."

Page 596.—Insert the following paragraph above the "Note":

"*Allowable Error.*—Percentages of silicon determined by the above method should be accurate to ± [0.005 + (0.02 × the percentage of silicon found)]."

Page 597.—Insert the same paragraph above the note on this page.

Page 599.—Insert the following paragraph above "Determination of Copper (Routine)":

"*Allowable Error.*—Percentages of copper determined by the above method should be accurate to ± [0.005 + (0.02 × the percentage of copper found)]."

NO. 25—TENTATIVE METHODS OF CHEMICAL ANALYSIS OF ALLOY STEELS: A 55 - 22 T[1]

Revise as follows, all page references refer to the *Proceedings* of the Society, Vol. 22, Part I (1922):

Page 602.—Insert the following paragraph above the "Notes":

"*Allowable Error.*—Percentages of nickel determined by the above method should be accurate to ± [0.005 + (0.01 × the percentage of nickel found)]."

Page 603.—Insert "(Routine)" over "I. Preliminary Treatment."

Page 606.—Under "Solutions Required," change the words "900 cc. of distilled water" to read as follows:

"distilled water, cool, and dilute to 1000 cc."

Page 606.—In the "Method," line 11, change "with HNO_3" to "with small portions of HNO_3."

Page 607.—Insert the following paragraph above the top "Note":

"*Allowable Error.*—Percentages of manganese determined by the above method should be accurate to ± [0.02 + (0.02 × the percentage of manganese found)]."

Page 607.—Change "Note" to "Notes" at the top of the page and add the following paragraph:

"The determination of manganese by the Ford or Ford-Williams method (preliminary separation of manganese as dioxide by boiling with concentrated nitric acid and potassium chlorate) is satisfactory for steels containing over 0.1 per cent of manganese. This method should not be used, however, except in laboratories which have excellent ventilation facilities."

Page 608.—In the "Method," line 7, change the words "H_2SO_4 are copiously evolved" to read as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 600 (1922).

"H_2SO_4 begins to come off. Do not prolong this treatment or allow the solution to go to dryness lest insoluble chromium and nickel sulfates be formed."

Page 610.—In the "Method," line 5, substitute "0.03 g." for "0.3 g."

Page 610.—Insert the following paragraph above "Determination of Nickel" at bottom of page:

"*Allowable Error.*—Percentages of chromium determined by the above method should be accurate to ± [0.01 + (0.01 × the percentage of chromium found)]."

Page 613.—Insert the following paragraph above the "Note":

"*Allowable Error.*—Percentages of phosphorus determined by the above method should be accurate to ± [0.003 + (0.02 × the percentage of phosphorus found)]."

Page 616.—At the bottom of the page insert the following paragraph:

"*Allowable Error.*—Percentages of vanadium determined by the above method should be accurate to ± [0.02 + (0.01 × the percentage of vanadium found)]."

Page 618.—Substitute the following for the matter given under the heading "Determination of Manganese by the Hydrolysis-Bismuthate Method (Absence of Cobalt)":

"See the Determination of Manganese in Chrome-Nickel Steel by the Hydrolysis-Bismuthate Method.

NOTES

"The retention of manganese by the bicarbonate precipitate is a little greater in steels containing tungsten than in steels containing no tungsten, but the retention is usually no more than from 0.01 to 0.02 per cent. In very accurate work this should be recovered as follows:

"Place the paper and precipitate in the original flask, add 20 cc. of HNO_3 (sp. gr. 1.42) shake until the paper is broken up, and then add 5 cc. of H_2SO_4 (sp. gr. 1.84). Heat over a free flame until fumes of sulfuric acid are given off, cool, and then add more HNO_3 and repeat the heating in case the organic matter has not been destroyed. Finally cool, wash down the sides of the flask, and evaporate again to the appearance of fumes of sulfuric acid and until all of the nitric acid has been expelled. Cool, dilute, neutralize with sodium hydroxide, then add sodium peroxide and boil. Chromium, vanadium, and tungsten are thus separated from manganese and iron, which should be filtered off, and washed with hot water containing a little sodium hydroxide. Dissolve the precipitate of iron and manganese in warm, dilute 1:1 nitric acid with the aid of a few drops of sulfurous acid if necessary, and add the solution to the original filtrate.

"Cobalt interferes in the above method. When this element is present the persulfate method must be used with a fresh sample as directed below, or in the filtrate obtained after the bicarbonate precipitation. In the latter event, acidify the filtrate with nitric acid, add 10 cc. of dilute sulfuric acid (1:1) and evaporate to a volume of 20 cc. Add 10 cc. of HNO_3 (sp. gr. 1.20) and proceed as directed below. With material containing much cobalt use one-fourth of the solution, which will represent 0.5 g. of steel."

Page 619.—Insert the following paragraph above "Determination of Manganese":

"*Allowable Error.*—Percentage of manganese determined by the above method should be accurate to ± [0.02 + (0.02 × the percentage of manganese found)]."

Page 619.—Under "Solutions Required," last paragraph, change the words "adding 50 cc. of water and 10 cc. of H_2SO_4," etc., to read as follows:

"reducing with a few drops of sulfurous acid and then proceeding as in the method below."

Page 621.—Insert the following paragraph above the "Note":

"*Allowable Error.*—Percentages of phosphorus determined by the above method should be accurate to ± [0.004 + (0.02 × the percentage of phosphorus found)]."

Page 623.—Insert the following paragraph after the "Method":

"*Allowable Error.*—Percentages of sulfur determined by the above method should be accurate to ± [0.004 + (0.02 × the percentage of sulfur found)]."

Page 624.—At the end of the "Method," insert:

"*Allowable Error.*—Percentages of silicon determined by the above method should be accurate to ± [0.02 + (0.02 × the percentage of silicon found)]."

Page 626.—Insert the following paragraph before the "Notes":

"*Allowable Error.*—Percentages of tungsten determined by the above method should be accurate to ± [0.05 + (0.01 × the percentage of tungsten found)]."

Page 627.—Insert the following paragraph above the heading "Determination of Vanadium":

"*Allowable Error.*—Percentages of chromium determined by the above method should be accurate to ± [0.01 + (0.02 × the percentage of chromium found)]."

Page 627.—Under "Determination of Vanadium by the Electrolytic Separation Method," substitute the following:

"See the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method. Proceed exactly as in this method until the bicarbonate precipitate and paper have been dissolved in sulfuric and nitric acids and all of the nitric acid has been expelled. Cool the solution, dilute with three times as much water as there is sulfuric acid present, warm to dissolve the soluble salts and filter through a small filter to remove the tungstic acid. Wash the paper and precipitate with small portions of dilute H_2SO_4 (1:3). Nearly neutralize the filtrate with NH_4OH (sp. gr. 0.90), evaporate, if necessary, to a volume of approximately 70 cc. and proceed with the electrolysis of the weakly acid solution and the determination of vanadium as in the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.

"*Allowable Error.*—Percentages of vanadium determined by the above method should be accurate to $\pm [0.03 + (0.01 \times$ the percentage of vanadium found$)]$."

Page 628.—Determination of Vanadium by Reduction with Ferrous Sulfate and Titration with Permanganate (Routine). Under this heading substitute the following:

SOLUTIONS REQUIRED

"*Dilute Hydrochloric Acid (2:1).*—Mix two parts of HCl (sp. gr. 1.19) with one part of water.

"*Dilute Nitric Acid (sp. gr. 1.20).*—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

"*Dilute Hydrochloric Acid (1:9).*—Mix 100 cc. of HCl (sp. gr. 1.19) and 900 cc. of distilled water.

METHOD

"(*a*) (When Cobalt does not exceed 1 per cent)

"Treat 2 g. of the steel in a porcelain dish with 70 cc. of dilute HCl (2:1) and heat until all action ceases. Cautiously add 10 cc. of dilute HNO_3 (sp. gr. 1.20) and evaporate the solution to dryness or to low bulk. Treat the residue with 45 cc. of dilute HCl (2:1) and heat until the soluble portion dissolves. Add an equal volume of water, boil for three minutes, filter and wash the residue thoroughly with dilute HCl (1:9) until free from iron. Evaporate the solution to small volume and destroy hydrochloric acid by small additions of nitric acid (sp. gr. 1.42) followed by boiling. If a residue appears, filter the solution. From this point proceed for chromium as in the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method and for Vanadium as in the Determination of Vanadium in Chrome-Vanadium Steel by Reduction with Ferrous Sulfate and Titration with Permanganate.

"(*b*) (When Cobalt exceeds 1 per cent)

"See the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.

"Proceed as described in this method until the bicarbonate precipitate has been washed with hot water. Return the paper and precipitate to the flask and add 60 cc. of dilute HCl (2:1). Heat the solution, add 10 cc. of HNO_3 (sp. gr. 1.20) and evaporate the solution to dryness or to a small volume. Treat the residue with 45 cc. of dilute HCl (2:1) and proceed as described above.

NOTES

"Tungsten interferes with the determination of vanadium by the above method and must be removed. While chromium can be determined in the presence of tungsten, it is conveniently determined in the same sample as is vanadium and the end point is easier to get when tungsten has been removed.

"In case hydrochloric acid is present when silver nitrate is added, enough of the latter must be added to take care of this before the regular addition is made.

"The pink color of cobalt interferes with the end point readings. If under 1 per cent, the color does not seriously affect the results, if over this, it should be removed."

Page 629.—After "Method," add:

"*Allowable Error.*—Percentages of nickel determined by the above method should be accurate to ± [0.02 + (0.01 × the percentage of nickel found)]."

Page 633.—Above "Notes," insert:

"*Allowable Error.*—Percentages of cobalt determined by the above method should be accurate to ± [0.04 + (0.01 × the percentage of cobalt found)]."

Page 638.—Above "Notes," insert:

"*Allowable Error.*—Percentages of molybdenum determined by the above method should be accurate to ± [0.02 + (0.02 × the percentage of molybdenum found)]."

NO. 26.—TENTATIVE SPECIFICATIONS FOR CARBON TOOL STEEL: A 71 - 21 T[1]

These specifications have been extensively revised and are appended hereto[2] in their proposed revised form, as well as the tentative Recommended Practice for Heat Treatment of Plain Carbon Tool Steel which is to appear as an appendix to the specifications.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 452 (1921).

[2] See p. 765.—ED.

EFFECT OF SULFUR ON ENDURANCE PROPERTIES OF RIVET STEEL

THIRD PRELIMINARY REPORT OF THE JOINT COMMITTEE ON INVESTIGATION OF PHOSPHORUS AND SULFUR IN STEEL[1]

The first preliminary report of the Joint Committee on Investigation of Phosphorus and Sulfur in Steel was entitled "Effect of Sulfur on Rivet Steel."[2] It described and gave results of various physical tests on bars and slabs from fourteen heats of rivet steel, Group I, Series A.[3] In Series A material, the sulfur present is residual, that is, it is sulfur that has entered the steel from the fuel, pig iron or scrap and remains throughout the process of manufacture.

The material used in this investigation was manufactured by the Carnegie Steel Co. under the supervision of the Joint Committee and is fully described in the first preliminary report. Table I, taken from the first report, gives the average chemical compositions of the fourteen heats. It was desired that the carbon and manganese contents of the various heats should be as nearly uniform as possible. The average carbon of all heats is 0.115 per cent, and it will be seen from Table I that the carbon content is fairly uniform; in only three heats (*A*, *F* and *G*) is it appreciably over the average. There is, however, a greater variation in the manganese content from the average of all heats, which is 0.442 per cent. Attention is called to the combination of the higher carbon and manganese contents of heats *F* and *G*, the effect of which was clearly indicated in the earlier tests described in the first preliminary report.

Endurance tests had not been completed at the time the first preliminary report was published. The present report gives results of such tests made at the U. S. Naval Engineering Experiment Station. All tests were made upon rivet bar material $\frac{63}{64}$ in. in diameter; that is, with the axis of the specimen parallel to the direction of rolling. No endurance tests were made on material taken from the slabs originally furnished.

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[1] Published by permission of the U. S. Bureau of Standards, the U. S. War Department and the U. S. Navy Department.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 94 (1922).

[3] For a brief statement of the organization of the Joint Committee and an outline of the investigation it has planned, see *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 136 (1923).

TABLE I.—AVERAGE CHEMICAL COMPOSITIONS, WITH MEAN DIVERGENCES.

Each value (except those for silicon) is the average for separate analyses on 14 samples from each heat. The values for silicon are the average of separate analyses on two samples from each heat.

The heats are arranged in the order of increasing sulfur contents.

Heat Letter	Ingot Hot or Cold	Sulfur, per cent	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Silicon, per cent
A..........	Cold	0.0282 ± 0.0015	0.136 ± 0.0037	0.426 ± 0.021	0.0062 ± 0.0005	0.002
F..........	Hot	0.0317 ± 0.0016	0.149 ± 0.0043	0.642 ± 0.0075	0.0082 ± 0.0017	0.004
H..........	Hot	0.0355 ± 0.0015	0.110 ± 0.0025	0.362 ± 0.0037	0.0055 ± 0.0015	0.008
G..........	Hot	0.0367 ± 0.0020	0.137 ± 0.0037	0.466 ± 0.0037	0.0085 ± 0.0015	0.057
B..........	Cold	0.0377 ± 0.0009	0.112 ± 0.0080	0.392 ± 0.012	0.0082 ± 0.0009	0.005
C..........	Cold	0.0444 ± 0.0026	0.107 ± 0.0075	0.455 ± 0.005	0.0082 ± 0.0012	0.009
J..........	Hot	0.0492 ± 0.0016	0.107 ± 0.0037	0.355 ± 0.0062	0.0062 ± 0.0027	0.010
K..........	Hot	0.0580 ± 0.0030	0.115 ± 0.0050	0.411 ± 0.0087	0.0105 ± 0.0025	0.002
E..........	Cold	0.0606 ± 0.0033	0.104 ± 0.0037	0.457 ± 0.006	0.0105 ± 0.0010	0.005
D..........	Cold	0.0608 ± 0.0012	0.094 ± 0.0040	0.385 ± 0.015	0.0127 ± 0.0020	0.002
P..........	Hot	0.0633 ± 0.0018	0.116 ± 0.0037	0.432 ± 0.005	0.0240 ± 0.0030	0.004
S..........	Hot	0.0695 ± 0.0028	0.104 ± 0.0043	0.420 ± 0.020	0.0117 ± 0.0003	0.003
R..........	Hot	0.0834 ± 0.0033	0.106 ± 0.0037	0.472 ± 0.0025	0.0112 ± 0.0030	0.007
M..........	Hot	0.1793 ± 0.0027	0.106 ± 0.0037	0.512 ± 0.0075	0.0060 ± 0.0030	0.002

DESCRIPTION OF TEST SPECIMENS AND METHODS OF TESTING

The two machines used in this investigation have been described elsewhere.[1,2,3] In one of the two types of test the specimens, held in modified White-Souther machines, were tested as rotating cantilevers. In the other type of test, specimens were tested in a high-speed alternating torsion machine of the inertia type.[2,3]

In the rotating cantilever test the tapered specimen,[3] shown in Fig. 1, was used. In this specimen, the taper is so adjusted that the stress is uniform within about 1.5 per cent over a length of $1\frac{1}{2}$ in. and the maximum stress is $\frac{3}{4}$ in. out from the fillet.

In the alternating torsion test, three methods of testing were used. The first method, which may be designated the "fatigue method," is that previously described.[2] In this method the specimen shown in Fig. 2 was used. The second method, the "deflection method," was described by Gough.[4] In this method the specimen shown in Fig. 3 was used. The third method, which may be called

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[1] D. J. McAdam, Jr., "Endurance of Steel Under Repeated Stresses," *Chemical and Metallurgical Engineering*, December 14, 1921.

[2] D. J. McAdam, Jr., "A High-Speed Alternating Torsion Testing Machine," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 366 (1920).

[3] D. J. McAdam, Jr., "Endurance Properties of Steel: Their Relation to Other Physical Properties and to Chemical Composition," *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 56. (1923).

[4] H. J. Gough, "Improvements in Methods of Fatigue Testing," *The Engineer*, August 12, 1921.

the "accelerated fatigue" method, was developed at the U. S. Naval Experiment Station and will be described fully at the annual meeting of the American Society for Testing Materials, June, 1924.[1]

HEAT TREATMENT

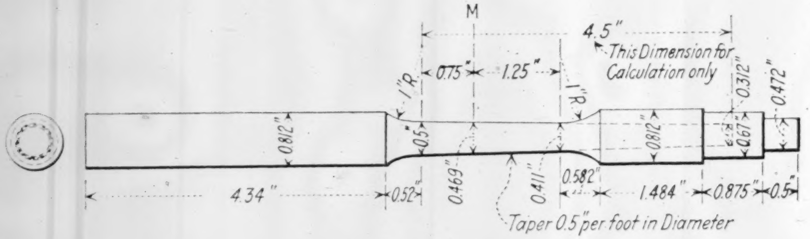
M
4.5"
This Dimension for Calculation only
1"R
0.75"
1.25"
1"R
0.312"
0.472"
0.812"
0.5"
0.812"
R
0.67"
0.469"
0.411"
0.582"
4.34"
0.52"
1.484"
0.875"
0.5"
Taper 0.5" per foot in Diameter

FIG. 1.—Rotating Cantilever Specimen, Type Cc

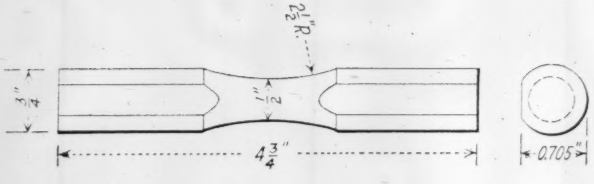
2½" R.
3/4"
1/2"
4 3/4"
0.705"

FIG. 2.—Alternating Torsion Specimen, Type F

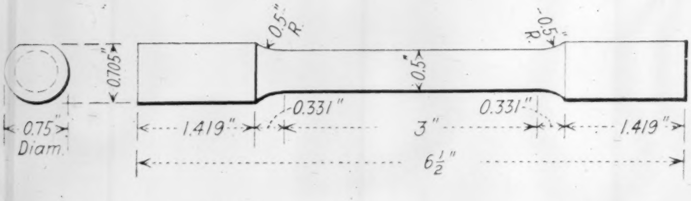
0.5" R
0.5" R
0.705"
0.5"
0.75" Diam.
1.419"
0.331"
3"
0.331"
1.419"
6½"

FIG. 3.—Alternating Torsion Specimen, Type R

For investigation of the endurance properties of rivet steel it seemed desirable to test the material in the softest and hardest condition in which it could normally exist as a result of heat treatment. For this purpose a set of bars of this material was annealed and another set was quenched as described in the First Preliminary Report of the Joint Committee.[2] The annealing treatment consisted in holding the steel at 940° C. (1725° F.) for one-half hour and cooling

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[1] D. J. McAdam, Jr., "Accelerated Fatigue Tests and Some Endurance Properties of Metals," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, 94 (1922).

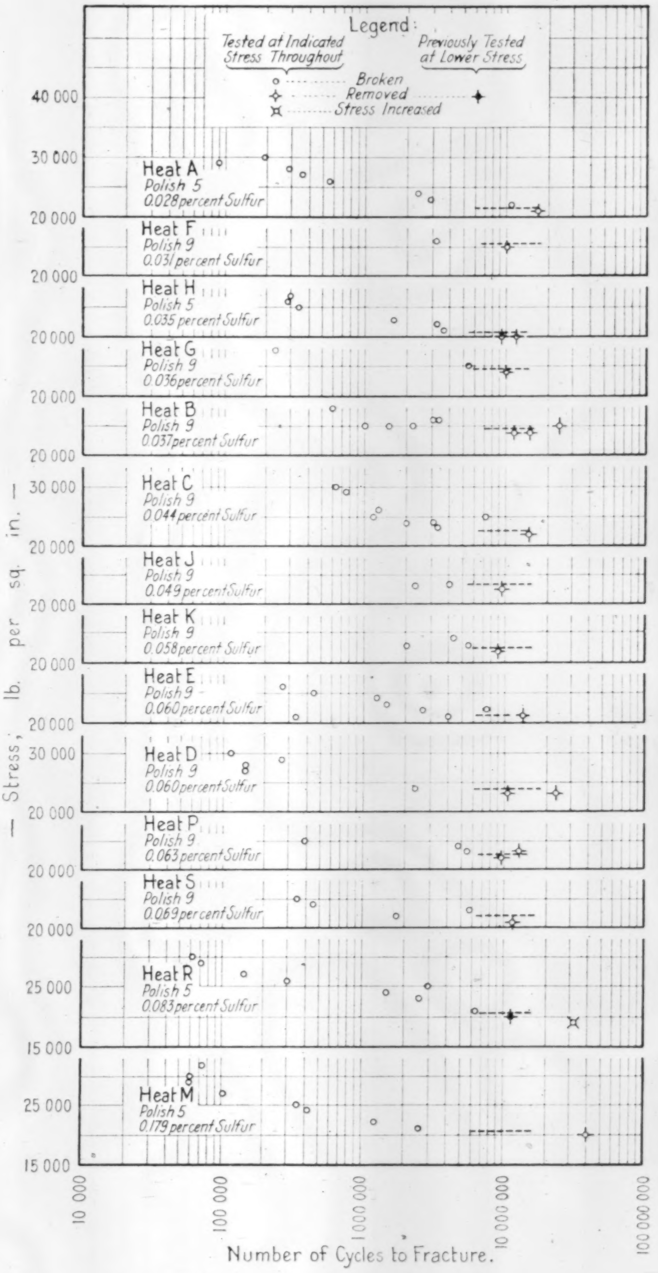

FIG. 4.—Rotating Cantilever Endurance Tests of Specimens from Rivet Bars in Annealed Condition.

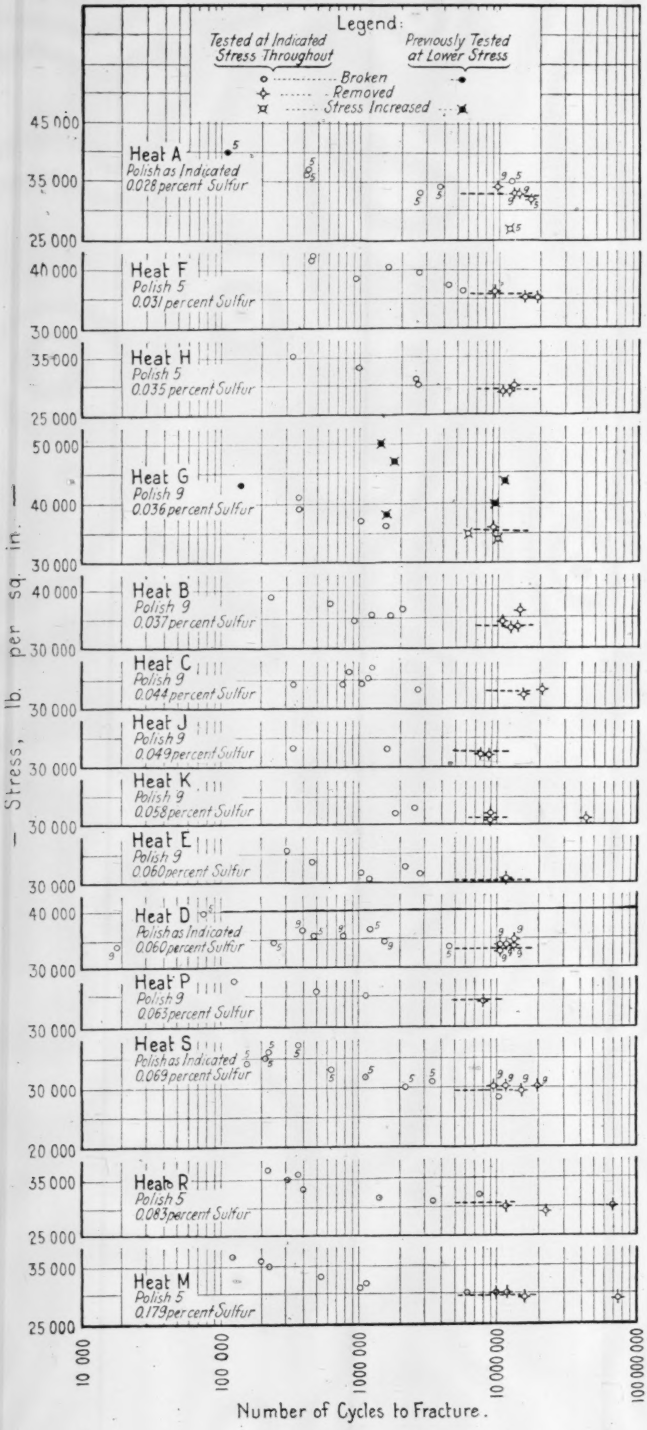

FIG. 5.—Rotating Cantilever Endurance Tests of Specimens from Rivet Bars in Quenched Condition.

in the furnace. The quenching treatment consisted in holding the material at 940° C. (1725° F.) for one-half hour and quenching in water at 21° C. (70° F.).

RESULTS OF ENDURANCE TESTS

Rotating Cantilever Method.—In recording the results of endurance tests, stresses are plotted as ordinates and cycles as abscissas on semilogarithmic paper. The results obtained with annealed and quenched material respectively are shown in Figs. 4 and 5. In these graphs the "endurance limits" for ten million cycles are indicated by short broken lines. The numerical results of these endurance limits are given in Column 6 of Tables II and III.

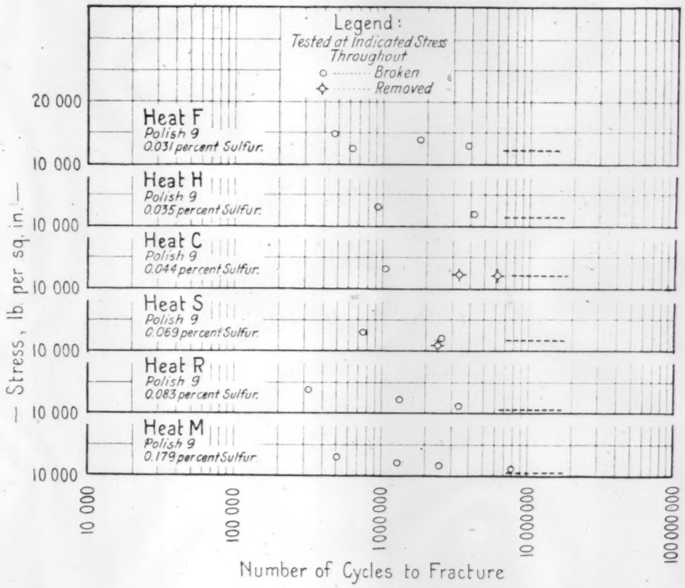

FIG. 6.—Alternating Torsion Endurance Tests of Specimens from Rivet Bars in Annealed Condition.

Alternating Torsion, "Fatigue Method."—In alternating torsion tests by the "fatigue method" the short specimen shown in Fig. 2 was used. Results obtained with annealed and quenched material respectively are shown in Figs. 6 and 7. In these figures the "endurance limits" for ten million cycles are indicated by short, broken lines. The numerical values are recorded in Column 7 of Tables II and III.

Alternating Torsion, "Deflection Method."—In an alternating

TABLE II.—RELATIONSHIP OF ENDURANCE LIMITS TO TENSILE STRENGTH AND TORSIONAL STRENGTH OF RIVET BARS (SERIES A, GROUP I)

ANNEALED MATERIAL

Heat	Sulfur, per cent	Cooled in	Average Tensile Strength, lb. per sq. in.[1]	Average Torsional Strength lb. per sq. in.[2]	Endurance Limit for 10 000 000 Cycles, lb. per sq. in.		Alternating Torsion Endurance Limit by Accelerated Fatigue Method, lb. per sq. in.	Ratio of Values							
					Rotating Cantilever	Alternating Torsion		Column 5 to Column 4	Column 7 to Column 6	Column 8 to Column 6	Column 6 to Column 4	Column 7 to Column 4	Column 8 to Column 4	Column 7 to Column 5	Column 8 to Column 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
A	0.028	Furnace	47 660	43 370	21 500	......	......	0.909	....	....	0.451	....	....	....	....
F	0.031	"	51 290	44 920	25 500	12 000	......	0.875	0.471	....	0.497	0.234	....	0.267	....
H	0.035	"	44 330	44 080	20 600	11 500	......	0.993	0.561	....	0.462	0.259	....	0.261	....
G	0.036	"	49 020	44 540	24 500	......	......	0.908	....	....	0.499	....	....	....	....
B	0.037	"	46 270	43 640	24 500	......	......	0.943	....	....	0.529	....	....	....	....
C	0.044	"	45 560	43 650	22 500	12 000	......	0.947	0.533	....	0.494	0.263	....	0.275	....
J	0.049	"	45 310	44 680	23 000	......	......	0.986	....	....	0.507	....	....	....	....
K	0.058	"	46 060	43 230	22 500	......	......	0.938	....	....	0.488	....	....	....	....
E	0.060	"	44 190	42 850	21 000	......	......	0.969	....	....	0.475	....	....	....	....
D	0.060	"	46 030	44 420	23 500	......	......	0.965	....	....	0.511	....	....	....	....
P	0.063	"	46 700	43 790	22 500	......	......	0.937	....	....	0.462	....	....	....	....
S	0.069	"	44 790	42 830	22 000	11 500	......	0.956	0.523	....	0.491	0.257	....	0.268	....
R	0.083	"	44 250	43 430	21 000	10 500	......	0.981	0.500	....	0.474	0.237	....	0.242	....
M	0.179	"	44 870	42 300	20 500	10 500	......	0.942	0.512	....	0.445	0.234	....	0.248	....
Average								0.946	0.517	....	0.486	0.247	....	0.260	....

[1] The values reported are those obtained at the Engineering Experiment Station, and are plotted as (x) in Fig. 6 of the first Preliminary Report, *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 108 (1922).

[2] The values reported are those obtained at the Engineering Experiment Station, and are plotted as (x) in Fig. 15 of the first Preliminary Report, *Ibid*, p. 114.

TABLE III.—RELATIONSHIP OF ENDURANCE LIMITS TO TENSILE STRENGTH AND TORSIONAL STRENGTH OF RIVET BARS (SERIES A, GROUP I)

QUENCHED MATERIAL

Heat	Sulfur, per cent	Cooled in	Average Tensile Strength, lb. per sq. in.[1]	Average Torsional Strength, lb. per sq. in.[2]	Endurance Limit for 10 000 000 Cycles, lb. per sq. in.		Alternating Torsion Endurance Limit by Accelerated Fatigue Method, lb. per sq. in.	Ratio of Values							
					Rotating Cantilever	Alternating Torsion		Column 5 to Column 4	Column 7 to Column 6	Column 8 to Column 6	Column 6 to Column 4	Column 7 to Column 4	Column 8 to Column 4	Column 7 to Column 5	Column 8 to Column 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
A	0.028	Water	67 140	55 250	33 000	......	......	0.823	....	....	0.492	....	....	....	....
F	0.031	"	69 920	56 940	35 500	22 500	19 000	0.814	0.634	0.535	0.507	0.322	0.272	0.395	0.334
H	0.035	"	64 420	54 200	29 500	18 500	17 000[a]	0.841	0.627	0.576	0.457	0.287	0.264	0.341	0.314
G	0.036	"	69 500	56 490	35 500	......	18 500	0.812	....	0.521	0.511	....	0.266	....	0.328
B	0.037	"	63 420	53 210	34 500	......	18 800	0.839	....	0.545	0.544	....	0.296	....	0.353
C	0.044	"	61 790	54 230	32 500	18 500	17 500	0.877	0.569	0.538	0.531	0.299	0.283	0.341	0.322
J	0.049	"	62 420	50 490	32 500	......	18 500	0.809	....	0.569	0.521	....	0.296	....	0.366
K	0.058	"	61 170	53 320	31 500	......	16 600	0.872	....	0.523	0.515	....	0.274	....	0.315
E	0.060	"	58 000	52 460	30 500	......	18 000	0.904	....	0.593	0.526	....	0.310	....	0.343
D	0.060	"	59 790	51 990	33 500	......	17 200	0.869	....	0.513	0.560	....	0.287	....	0.331
P	0.063	"	62 170	52 320	34 500	......	17 300	0.841	....	0.501	0.555	....	0.278	....	0.331
S	0.069	"	60 920	51 620	29 500	17 500	......	0.847	0.593	....	0.484	0.287	....	0.339	....
R	0.083	"	58 910	53 090	30 500	19 000	18 000	0.882	0.623	0.590	0.518	0.322	0.306	0.358	0.339
M	0.179	"	59 530	49 220	29 500	19 000	16 100[a]	0.827	0.644	0.546	0.496	0.319	0.269	0.386	0.327
Average								0.847	0.617	0.547	0.515	0.306	0.283	0.360	0.334

[a] Obtained by "deflection" method.

[1] The values reported are those obtained at the Engineering Experiment Station, and are plotted as (x) in Fig. 7 of the first Preliminary Report, *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 109 (1922).

[2] The values reported are those obtained at the Naval Engineering Experiment Station, and are plotted as (x) in Fig. 16 of the first Preliminary Report, *Ibid*, p. 115.

torsion test with the inertia machine developed at the Naval Experiment Station,[1] the amplitude of oscillation of the fly wheel depends not only on the radius of crank-pin motion but on the twist of the specimen. The amount of this twist is readily measured by means of the optical lever system used in this test. Stress-strain graphs may therefore be obtained by gradually increasing the speed of the machine and taking readings at regular intervals. It was considered desirable to use such stress-strain diagrams as a possible means of obtaining endurance limits by the "deflection method" described by Gough.[2] For this purpose the "R type" specimen shown in Fig. 3 was used. This specimen had been previously adopted for the purpose of obtaining endurance limits by the "accelerated fatigue method"

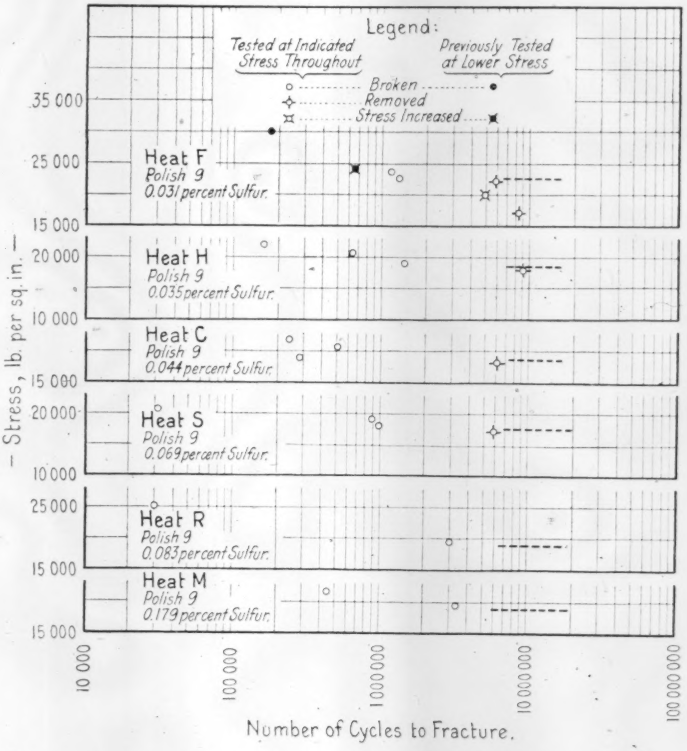

FIG. 7.—Alternating Torsion Endurance Tests of Specimens from Rivet Bars in Quenched Condition.

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[1] D. J. McAdam, Jr., "A High-Speed Alternating Torsion Testing Machine," *Proceedings*, Am. Soc. Testing Mats., Vol., XX, Part II, p. 366 (1920).

[2] H. J. Gough, "Improvements in Methods of Fatigue Testing," *The Engineer*, August 12, 1921.

and had been used with varying success in attempts to obtain endurance limits of various steels and non-ferrous metals by the deflection method.

In obtaining endurance limits by the deflection method, stress-deflection graphs are plotted and an attempt is made to determine the stress above which the graph ceases to be a straight line; in other words the stress above which increase of deflection is not proportional to increase of stress. This point is analogous to the proportional limit as determined in a tension test.

It should be emphasized that there is no *a priori* reason for assuming that the limit of proportionality in the stress-deflection graph (as determined by means of a specimen under rapid alternations of stress) corresponds to an "endurance limit." Gough,[1] however, determined experimentally that this origin of curvature in a stress-deflection graph actually corresponds rather closely to the "endurance limit" in the case of some steels. Investigation of this method at the Naval Experiment Station has shown that it is not applicable to non-ferrous metals in general and probably not to all steels.

It was found that stress-deflection graphs obtained with the rivet steels under investigation are approximately straight lines up to stresses of about 19,000 to 21,000 lb. per sq. in. The curvature at first is so slight, however, that it is difficult to determine within 1000 or 2000 lb. per sq. in. a definite origin of curvature. "Endurance limits" obtained by this method, therefore, would not be accurate within 1000 or 2000 lb. per sq. in. For this reason the deflection method was abandoned. Two results, however, are recorded in Table III.

Alternating Torsion, "Accelerated Fatigue Method."—In the "accelerated fatigue" method the long specimen shown in Fig. 3 was used. Readings indicating amplitude of oscillation of fly wheel were taken over a suitable range of speed. Instead of merely taking one reading at each speed, as in the deflection method, however, the machine was allowed to run for intervals of about 15 or 20 minutes at each speed. Below the endurance limit, the light-beam reading remained constant throughout the interval at constant speed. Above stresses varying with the material but ranging from 16,000 to 19,000 lb. per sq. in., the light-beam reading increased during the interval at constant speed. Stress-strain graphs plotted from results obtained in this way show a more definite origin of curvature than when obtained by the deflection method. With some metals, however, as described elsewhere,[1] the interval at constant speed must be considerably longer than the 15 or 20-minute interval used with rivet steel.

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[1] H. J. Gough, "Improvements in Methods of Fatigue Testing," *The Engineer*, August 12, 1921.

It should be pointed out that the "accelerated fatigue" method does not depend on determination of a limit of proportionality of deflection to stress as does the "deflection method." The "accelerated fatigue" method consists in determination of the stress above which the deflection at constant speed gradually increases automatically until the specimen breaks. This automatically accelerated increase of stress causes the specimen to fail after much fewer cycles than if the nominal stress were constant as in the ordinary fatigue test. For this reason it may be called the "accelerated fatigue" method.

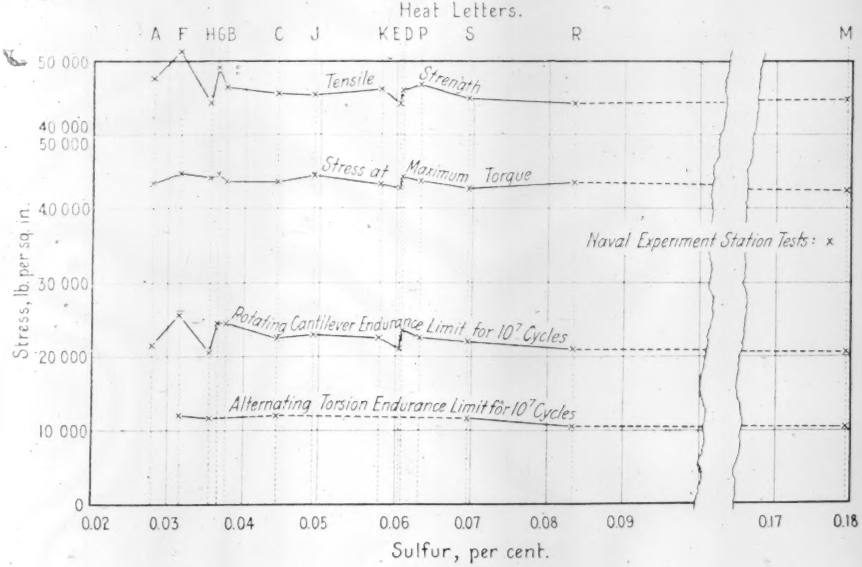

FIG. 8.—Comparison of Tensile and Torsional Strength and Endurance Properties of Specimens from Rivet Bars in Annealed Condition.

A comparison of Columns 7 and 8 of Table III shows that the results obtained by the "accelerated fatigue" method are slightly lower than the "endurance limits" for ten million cycles obtained by the "fatigue method." This would seem to indicate that the endurance graphs shown in Figs. 4 and 5 would retain a slight downward slope for considerably more than ten million cycles of stress.

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[1] D. J. McAdam, Jr., "Accelerated Fatigue Tests and Some Endurance Properties of Metals," *Proceedings*, Am. Soc. Testing Mats, Vol. 24, Part II (1924).

Due to lack of time or material, alternating torsion results were not obtained for all the heats of rivet steel.

RELATION OF ENDURANCE LIMITS TO OTHER PROPERTIES

In order to bring out more clearly the relationship between endurance properties and sulfur content of these steels, the endurance limits have been plotted in Figs. 8 and 9 in a manner similar to that followed in the first preliminary report. In Fig. 8 the rotating cantilever and alternating torsion endurance limits for annealed material are plotted.

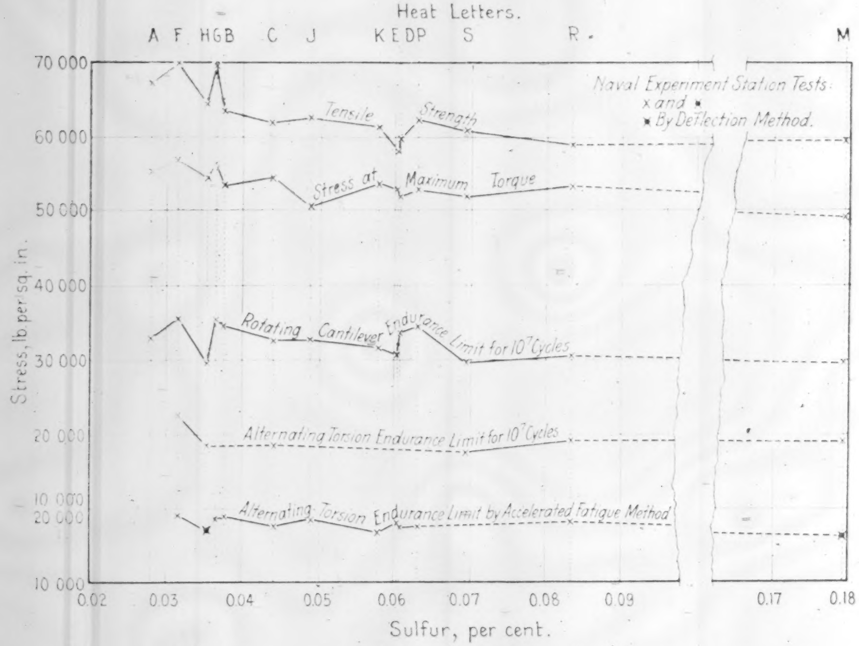

FIG. 9.—Comparison of Tensile and Torsional Strength and Endurance Properties of Specimens from Rivet Bars in Quenched Condition.

The same properties for quenched material are plotted in Fig. 9, in which are plotted also the alternating torsion endurance limits determined by the accelerated fatigue method.

The relationship of the endurance limits to other physical properties is given in Columns 9 to 16, inclusive, of Tables II and III. The average tensile strength and stress at maximum torque (torsional strength) given in Columns 4 and 5 of these tables and plotted also in Figs. 8 and 9, which form the basis of the ratios reported in the tables, are those obtained by the Naval Experiment Station in the original investigation[1] and are not the averages of the values determined at the Naval Experiment Station and at Watertown Arsenal, represented by the curves drawn in the first preliminary report. The Joint Committee considered it more logical in making these comparisons to use the Naval Experiment Station values, in view of the fact that the specimens for endurance tests were taken from the same bars from which the Naval Experiment Station had obtained the specimens for their tension and torsion tests.

The relationship between endurance limit and tensile strength and stress at maximum torque is brought out clearly in Figs. 8 and 9. It will be noted that there is marked agreement in the general trends of the tensile strength and rotating cantilever endurance limit curves for both annealed and quenched material. The effect of the high carbon and manganese contents of heats *F* and *G* previously noted is clearly evident in the endurance limits. The relationship of rotating cantilever endurance limit to stress at maximum torque is also conspicuous. Due to the smaller numerical values for alternating torsion endurance limit, slight experimental errors make the relationship to tensile strength and stress at maximum torque less conspicuous.

Respectfully submitted on behalf of the Joint Committee,

GEORGE K. BURGESS,
Chairman.

C. L. WARWICK,
Secretary.

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[1] The values in Column 4 of Tables II and III are plotted as (**x**) in Figs. 6 and 7 of the first preliminary report; the values in Column 5 in Figs. 15 and 16 of that report. See *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 94 (1922).

METALLOGRAPHIC INVESTIGATION OF EFFECT OF SULFUR ON RIVET STEEL

FOURTH PRELIMINARY REPORT OF THE JOINT COMMITTEE ON INVESTIGATION OF PHOSPHORUS AND SULFUR IN STEEL[1]

The first preliminary report of the Joint Committee on Investigation of Phosphorus and Sulfur in Steel dealt with the "Effect of Sulfur on Rivet Steel."[2] It described and gave results of physical tests on bars and slabs from fourteen heats of rivet steel, Group I, Series A.[3] In Series A material, the sulfur is residual, that is, sulfur that has entered the steel from the fuel, pig iron or scrap and remained throughout the process of manufacture. The material used in this investigation was manufactured by the Carnegie Steel Co. under the supervision of the Joint Committee and is fully described in the first preliminary report. The material was furnished in the form of bars $\frac{63}{64}$ in. in diameter and slabs $5\frac{1}{4}$ by 1 in. in cross-section. Table I, taken from the first report, gives the average chemical compositions of the fourteen heats. It was desired that the carbon and manganese contents of the various heats should be as nearly uniform as possible. The average carbon of all heats is 0.115 per cent, and it will be seen from Table I that the carbon content is fairly uniform; in only three heats (*A*, *F* and *G*) is it appreciably over the average. There is, however, a greater variation in the manganese content from the average of all heats, which is 0.442 per cent.

The present report gives results of a metallographic investigation of this material. Both the bar and slab material have been studied. For purposes of comparison, a number of commercial rivet steels were obtained from various manufacturers by the Joint Committee in the form of short bars taken from material being supplied on current commercial orders about June, 1923. No physical tests have been made on this material, the quantity received in most cases being too small. A metallographic examination has been made, however, and the results are included in this report.

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[1] Published by permission of the U. S. Bureau of Standards, the U. S. War Department, and the U. S. Navy Department.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 94 (1922).

[3] For a brief statement of the organization of the Joint Committee and an outline of the investigation it has planned, see *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 136 (1923).

The metallographic investigation on which the present report is based was made at the U. S. Naval Engineering Experiment Station, Annapolis, Md.,[1] and the report has been prepared for the Joint Committee by D. J. McAdam, Metallurgist of that station and a member of the committee. The metallographic investigation may be classified in three divisions: macroscopic investigations, investigation of non-metallic inclusions, and investigation of microstructure.

TABLE I.—AVERAGE CHEMICAL COMPOSITIONS, WITH MEAN DIVERGENCES.

Each value (except those for silicon) is the average for separate analyses on 14 samples from each heat. The values for silicon are the average of separate analyses on two samples from each heat.

The heats are arranged in the order of increasing sulfur contents.

Heat Letter	Ingot Hot or Cold	Sulfur, per cent	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Silicon, per cent
A	Cold	0.0282 ± 0.0015	0.136 ± 0.0037	0.426 ± 0.021	0.0062 ± 0.0005	0.002
F	Hot	0.0317 ± 0.0016	0.149 ± 0.0043	0.642 ± 0.0075	0.0082 ± 0.0017	0.004
H	Hot	0.0355 ± 0.0015	0.110 ± 0.0025	0.362 ± 0.0037	0.0055 ± 0.0015	0.008
G	Hot	0.0367 ± 0.0020	0.137 ± 0.0037	0.466 ± 0.0037	0.0085 ± 0.0015	0.057
B	Cold	0.0377 ± 0.0009	0.112 ± 0.0080	0.392 ± 0.012	0.0082 ± 0.0009	0.005
C	Cold	0.0444 ± 0.0026	0.107 ± 0.0075	0.455 ± 0.005	0.0082 ± 0.0012	0.009
J	Hot	0.0492 ± 0.0016	0.107 ± 0.0037	0.355 ± 0.0062	0.0062 ± 0.0027	0.010
K	Hot	0.0580 ± 0.0030	0.115 ± 0.0050	0.411 ± 0.0087	0.0105 ± 0.0025	0.002
E	Cold	0.0606 ± 0.0033	0.104 ± 0.0037	0.457 ± 0.006	0.0105 ± 0.0010	0.005
D	Cold	0.0608 ± 0.0012	0.094 ± 0.0040	0.385 ± 0.015	0.0127 ± 0.0020	0.002
P	Hot	0.0633 ± 0.0018	0.116 ± 0.0037	0.432 ± 0.005	0.0240 ± 0.0030	0.004
S	Hot	0.0695 ± 0.0028	0.104 ± 0.0043	0.420 ± 0.020	0.0117 ± 0.0003	0.003
R	Hot	0.0834 ± 0.0033	0.106 ± 0.0037	0.472 ± 0.0025	0.0112 ± 0.0030	0.007
M	Hot	0.1793 ± 0.0027	0.106 ± 0.0037	0.512 ± 0.0075	0.0060 ± 0.0030	0.002

MACROSCOPIC INVESTIGATION

After trying various methods of macro-etching it was found that sulfur prints give the best indication of the macrostructure.

For the investigation of the bar material a sulfur print was made of a full-size cross-section and of a longitudinal section of each of the four bars available from each heat of steel. Photographs of these are

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[1] The metallographic investigation was conducted by D. J. McAdam, Jr., Metallurgist, and George F. Wohlgemuth, Associate Metallurgist, of the U. S. Naval Engineering Experiment Station.

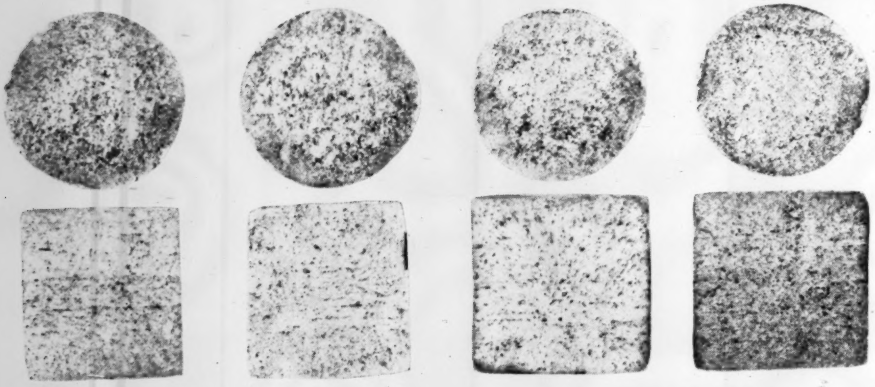

FIG. 1.—Heat *A:* S = 0.028. Second Print, 5-per-cent Acid, 6 min.

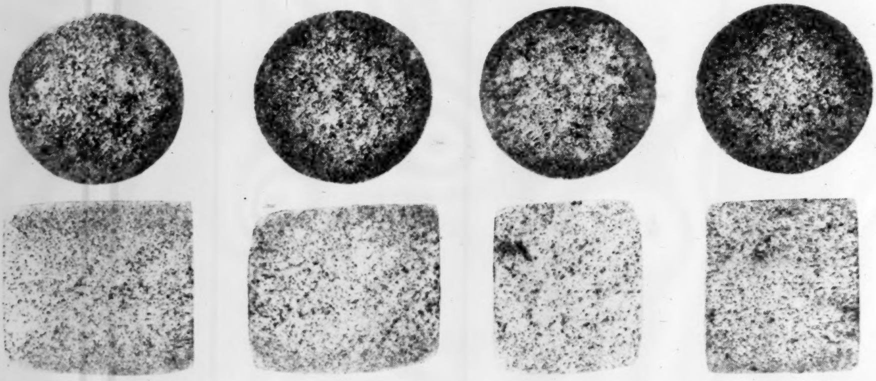

FIG. 2.—Heat *F:* S = 0.031. Second Print, 5-per-cent Acid, 5 min.

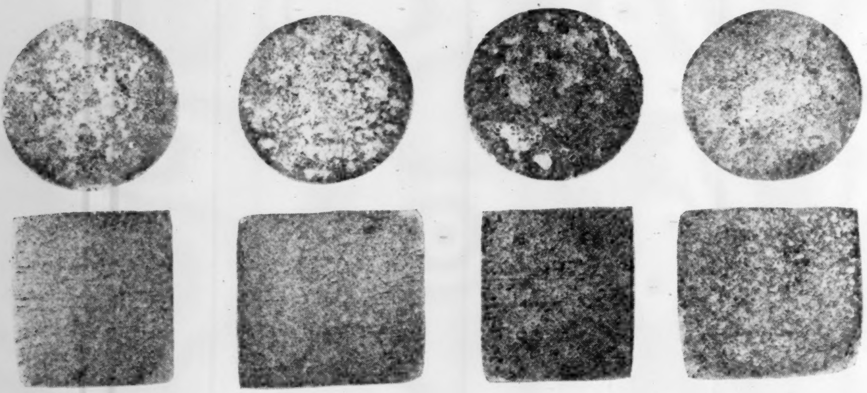

FIG. 3.—Heat *H:* S = 0.035. Second Print, 5-per-cent Acid, 5 min.

PLATE I.—SULFUR PRINTS OF RIVET BARS. FULL SIZE.

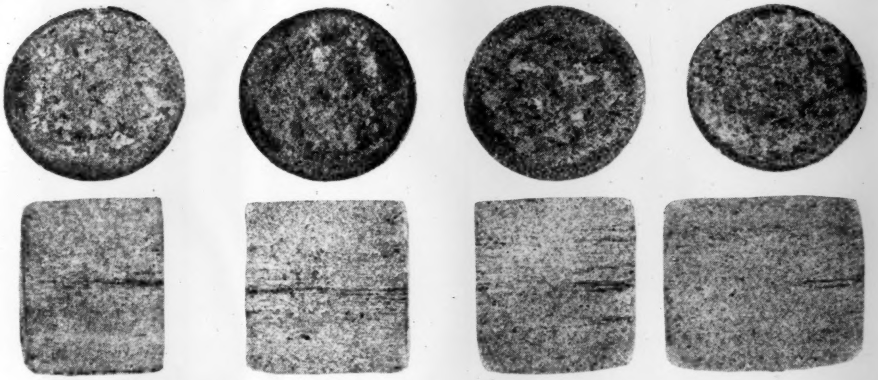

Fig. 4.—Heat *G:* S = 0.036. Second Print, 5-per-cent Acid, 5 min.

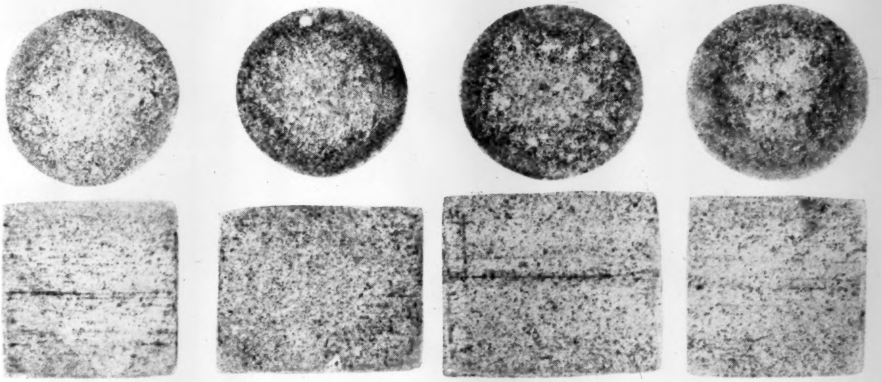

Fig. 5.—Heat *B:* S = 0.037. Second Print, 5-per-cent Acid, 5 min.

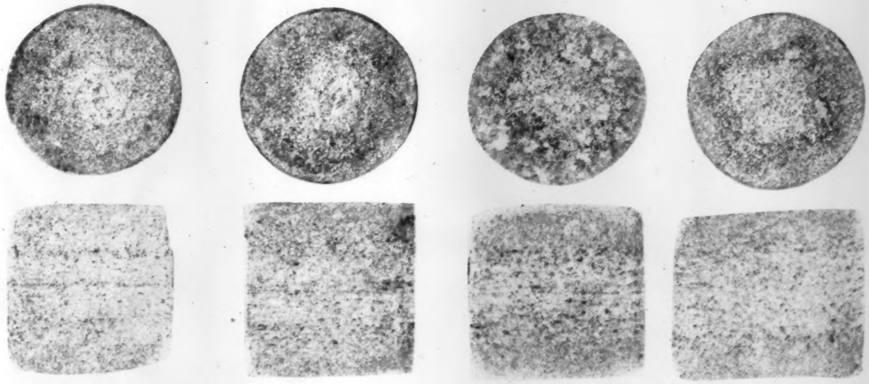

Fig. 6.—Heat *C:* S = 0.044. Second Print, 5-per-cent Acid, 5 min.

Plate II.—Sulfur Prints of Rivet Bars. Full Size.

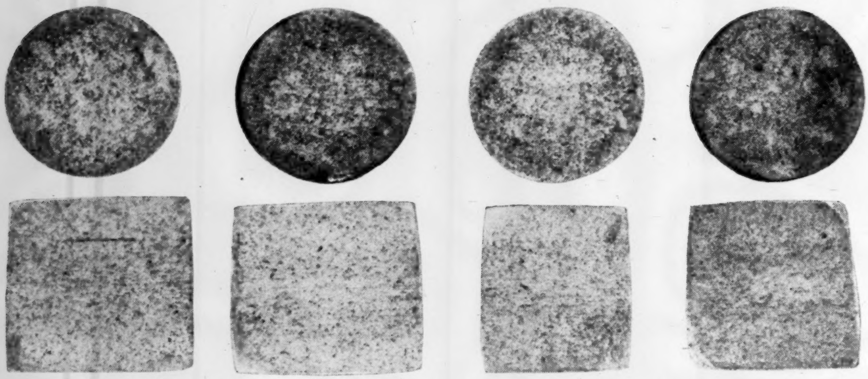

FIG. 7.—Heat *J:* S = 0.049. Second Print, 5-per-cent Acid, $4\frac{1}{2}$ min.

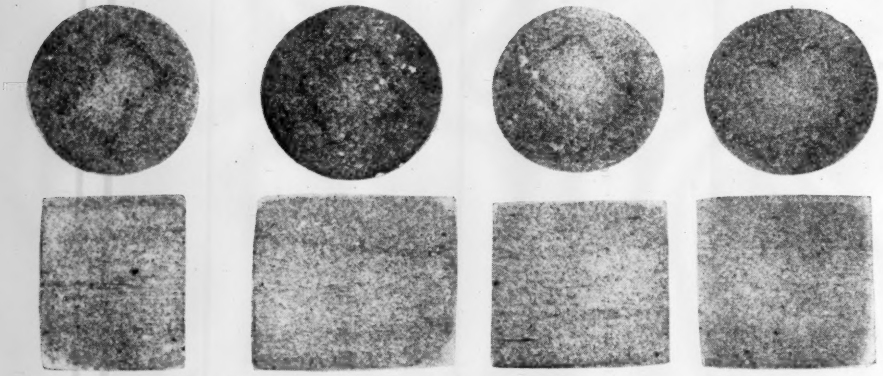

FIG. 8.—Heat *K:* S = 0.058. Second Print, 5-per-cent Acid, $4\frac{1}{2}$ min.

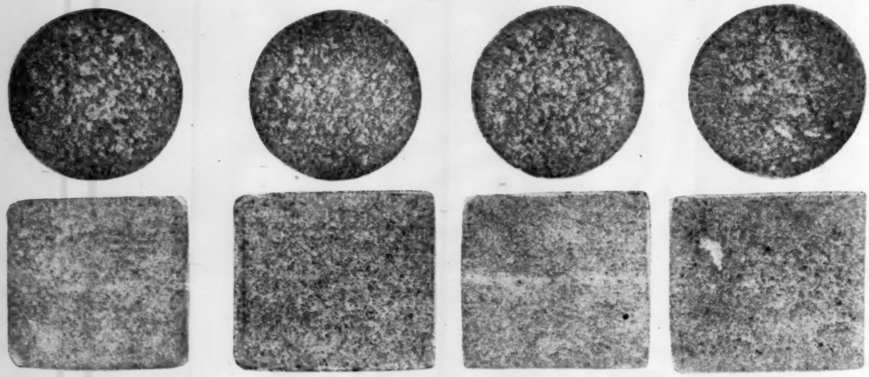

FIG. 9.—Heat *D:* S = 0.060. Second Print, 5-per-cent Acid, 3 min.

PLATE III.—SULFUR PRINTS OF RIVET BARS. FULL SIZE.

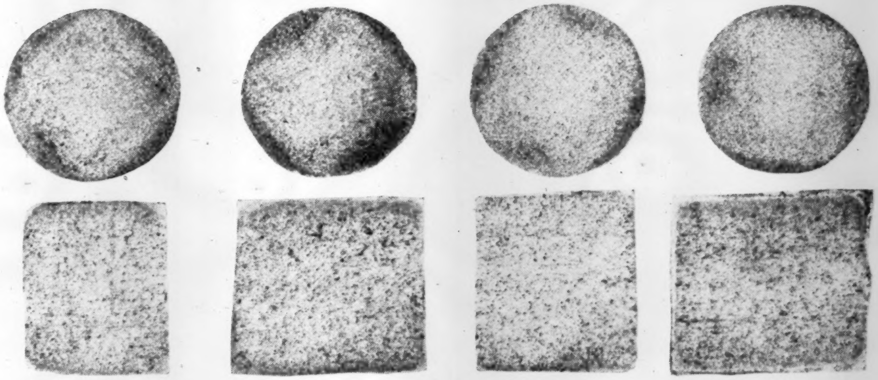

FIG. 10.—Heat *E:* S = 0.060. Second Print, 5-per-cent Acid, 3 min.

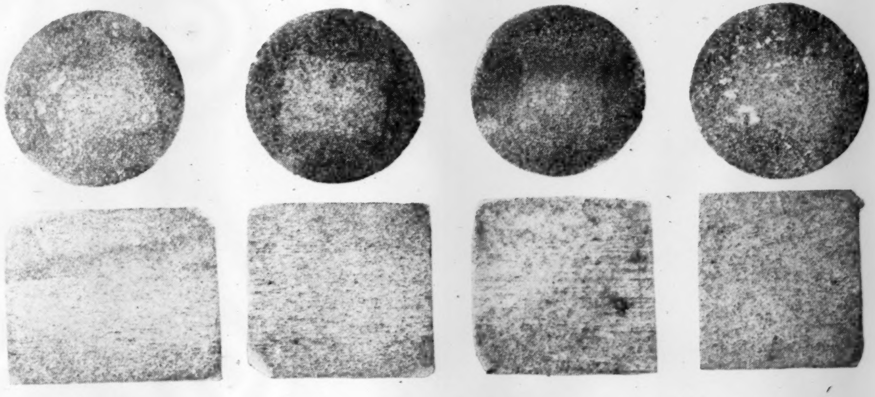

FIG. 11.—Heat *P:* S = 0.063. Second Print, 5-per-cent Acid, 3 min.

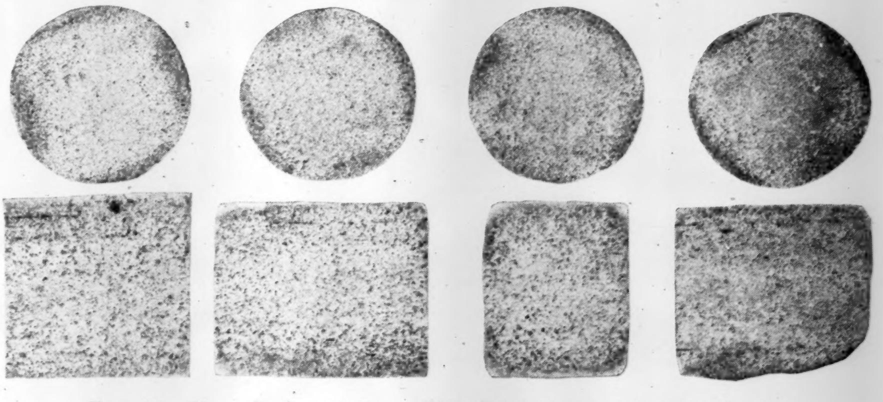

FIG. 12.—Heat *S:* S = 0.069. First Print, 3-per-cent Acid, 2½ min.

PLATE IV.—SULFUR PRINTS OF RIVET BARS. FULL SIZE.

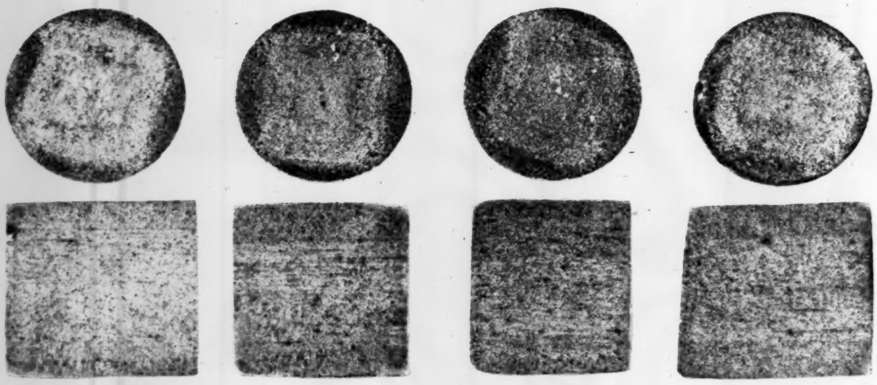

FIG. 13.—Heat *R:* S = 0.083. Second Print, 3-per-cent Acid, 1 min.

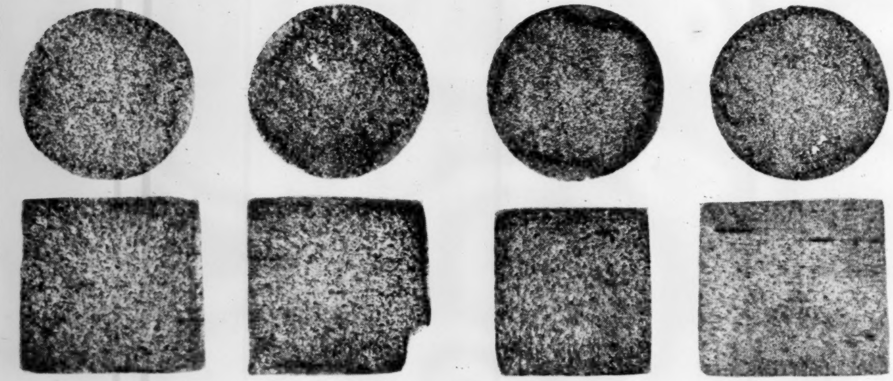

FIG. 14.—Heat *M:* S = 0.179. Third Print, 3-per-cent Acid, 1 min.

PLATE V.—SULFUR PRINTS OF RIVET BARS. FULL SIZE.

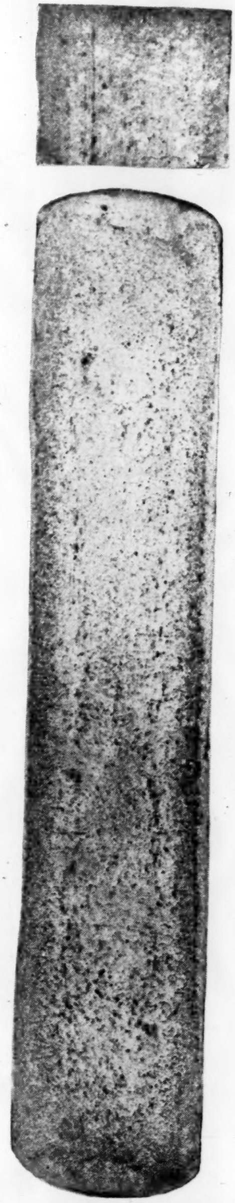

FIG. 15.—Heat *A:*
S = 0.028.
First Print, 5-per-cent
Acid, 3 min.

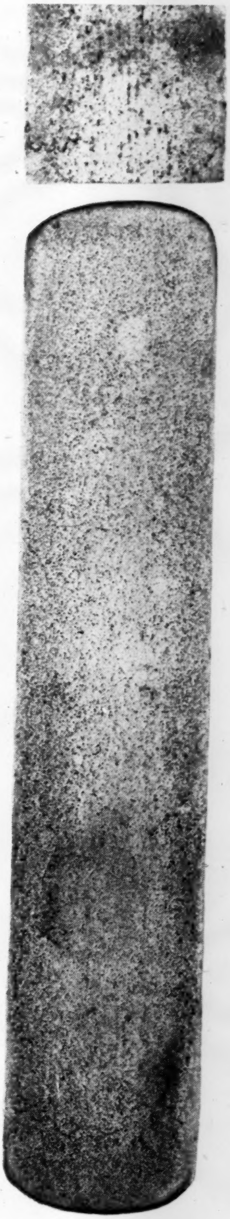

FIG. 16.—Heat *F:*
S = 0.031.
First Print, 5-per-cent
Acid, 3 min.

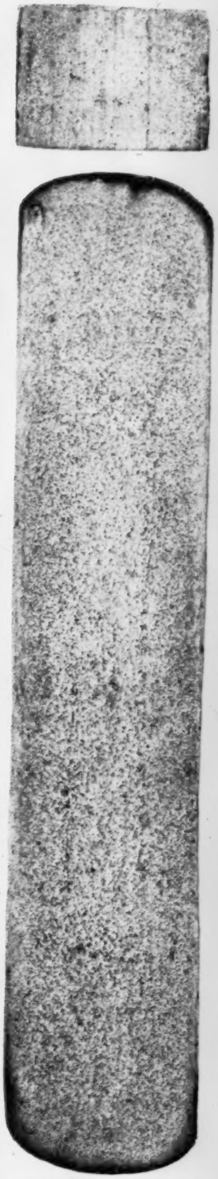

FIG. 17.—Heat *H:*
S = 0.035.
First Print, 5-per-cent
Acid, 3 min.

PLATE VI.—SULFUR PRINTS OF SLABS OF RIVET STEEL. FULL SIZE.

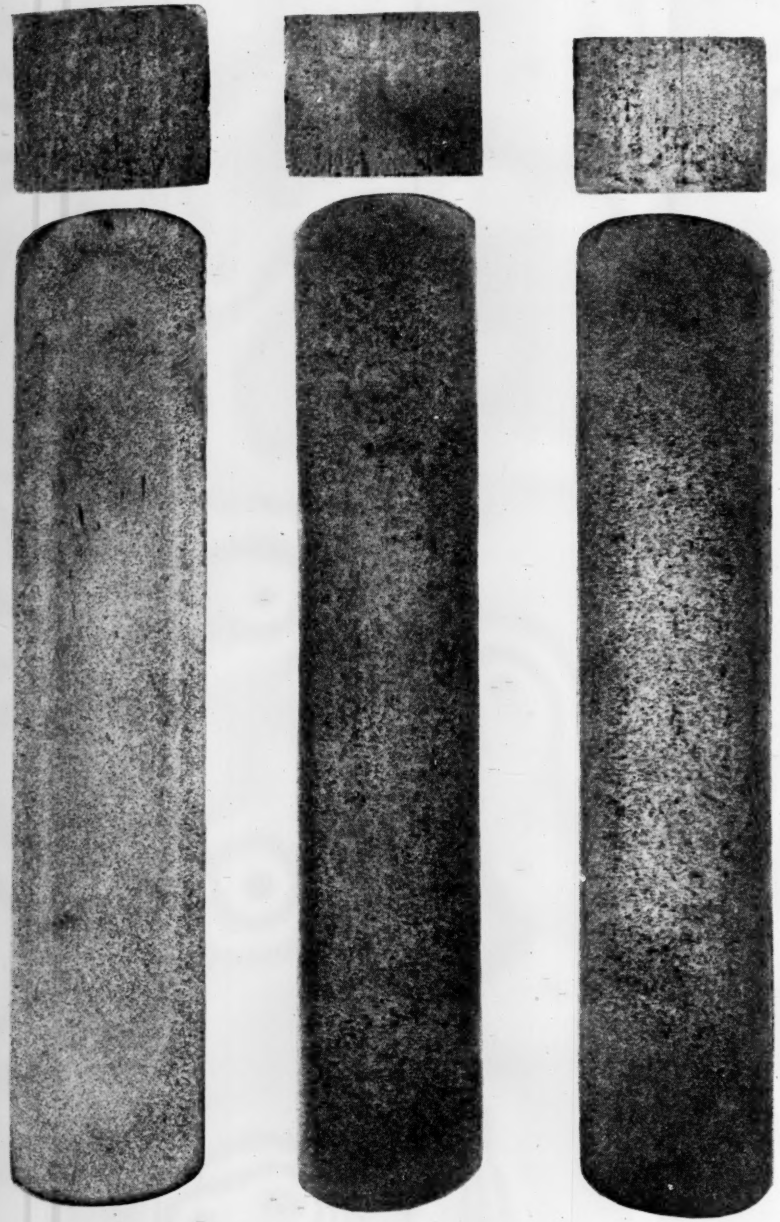

FIG. 18.—Heat *G:*
$S = 0.036$.
First Print, 5-per-cent
Acid, 3 min.

FIG. 19.—Heat *B:*
$S = 0.037$.
Second Print, 5-per-cent
Acid, 2 min.

FIG. 20.—Heat *C:*
$S = 0.044$.
Second Print, 5-per-cent
Acid, 2 min.

PLATE VII.—SULFUR PRINTS OF SLABS OF RIVET STEEL. FULL SIZE.

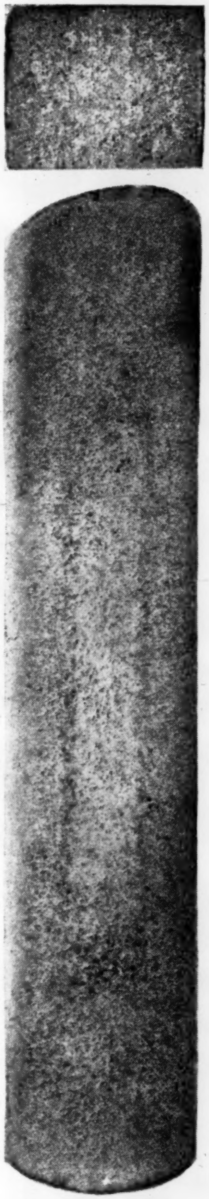

FIG. 21.—Heat *J:*
S = 0.049.
First Print, 5-per-cent
Acid, 2 min.

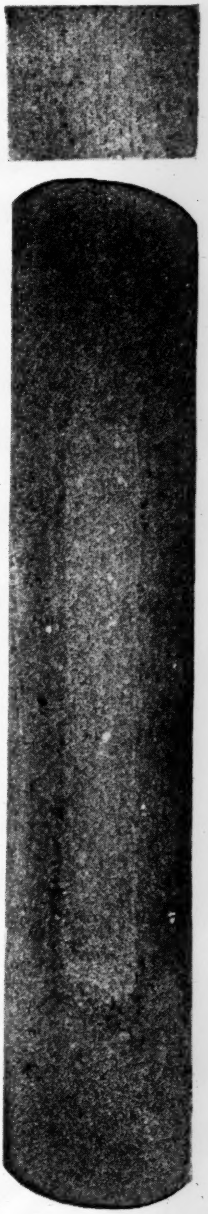

FIG. 22.—Heat *K:*
S = 0.058.
First Print, 5-per-cent
Acid, 2 min.

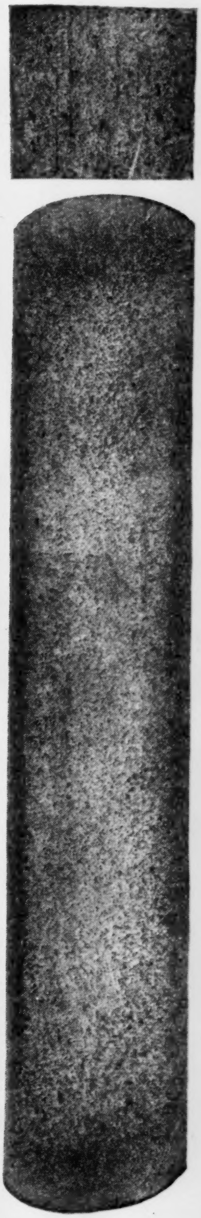

FIG. 23.—Heat *D:*
S = 0.060.
First Print, 5-per-cent
Acid, 2 min.

PLATE VIII.—SULFUR PRINTS OF SLABS OF RIVET STEEL. FULL SIZE.

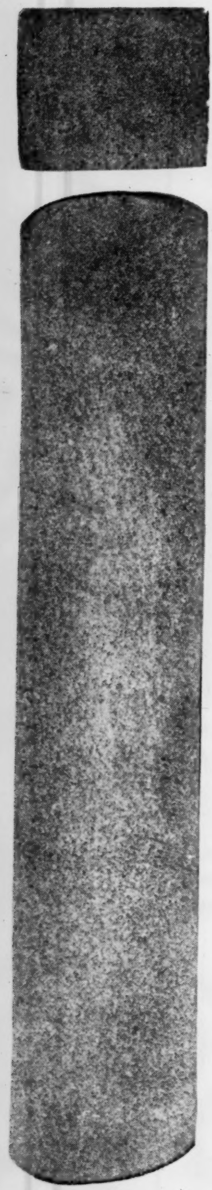

FIG. 24.—Heat *E:*
S = 0.060.
Second Print, 5-per-cent
Acid, 3 min.

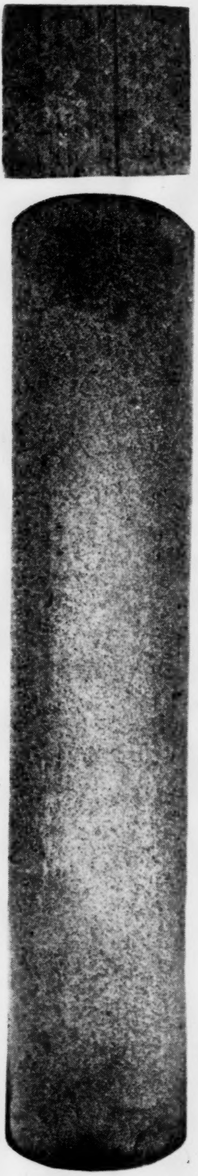

FIG. 25.—Heat *P:*
S = 0.063.
First Print, 5-per-cent
Acid, 2½ min.

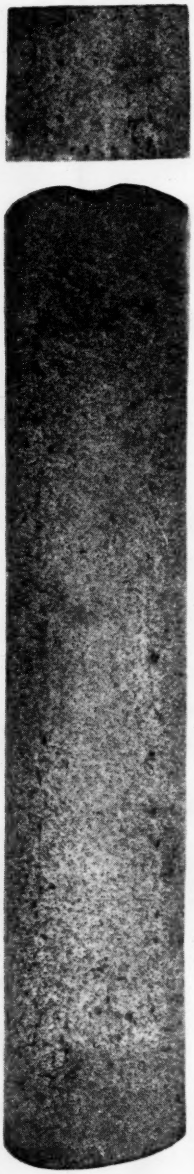

FIG. 26.—Heat *S:*
S = 0.069.
Second Print, 3-per-cent
Acid, 45 sec.

PLATE IX.—SULFUR PRINTS OF SLABS OF RIVET STEEL. FULL SIZE.

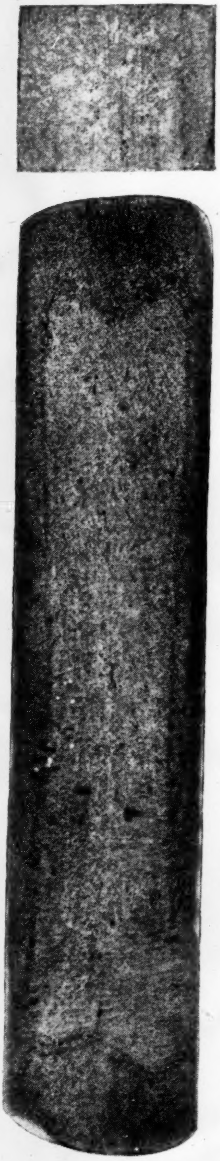

FIG. 27.—Heat *R:*
S = 0.083.
Third Print, 3-per-cent
Acid, 1½ min.

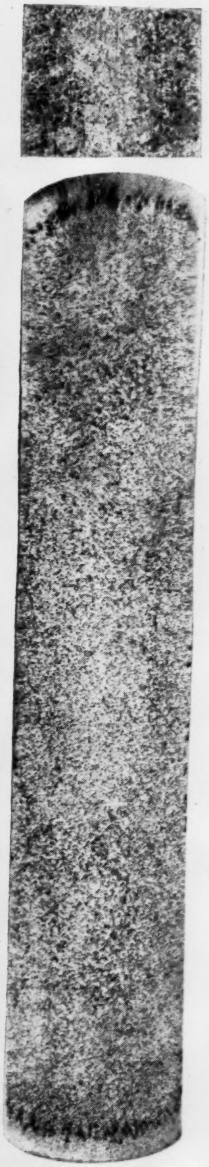

FIG. 28.—Heat *M:*
S = 0.179.
First Print, 3-per-cent
Acid, 45 sec.

PLATE X.—SULFUR PRINTS OF SLABS OF RIVET STEEL. FULL SIZE.

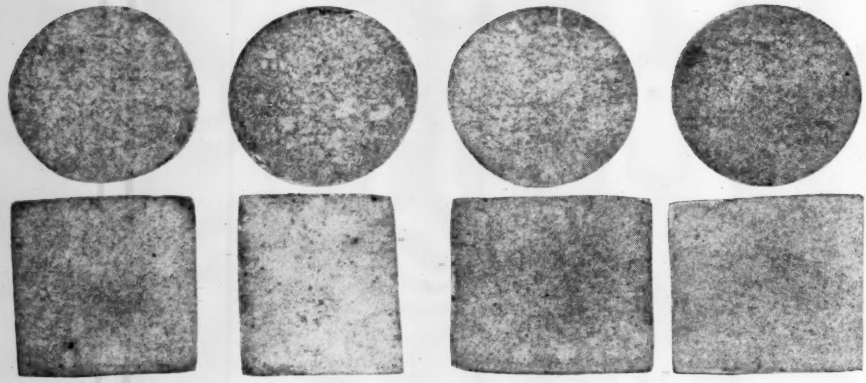

FIG. 29.—Manufacturer No. 1: S = 0.027. Second Print, 5-per-cent Acid, 8 min.

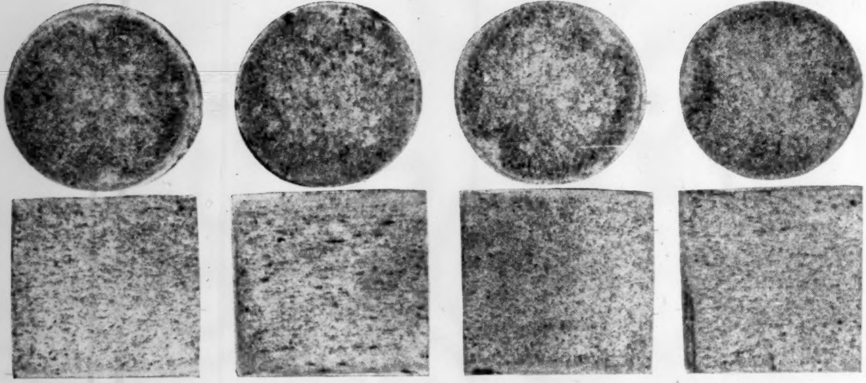

FIG. 30.—Manufacturer No. 2: S = 0.028. Second Print, 5-per-cent Acid, 5 min.

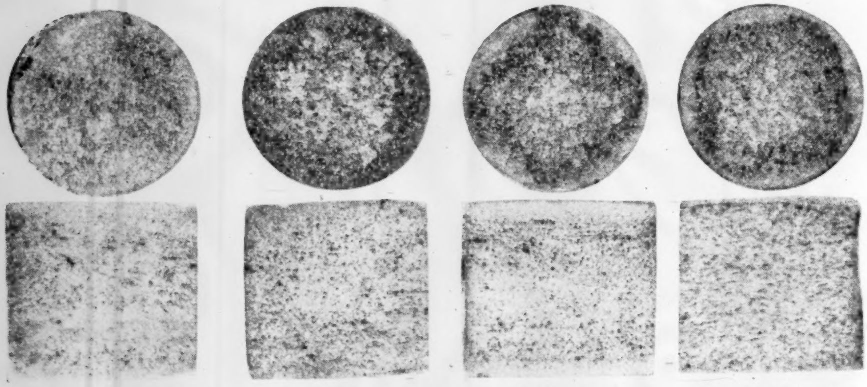

FIG. 31.—Manufacturer No. 3: S = 0.037. Second Print, 5-per-cent Acid, 5 min.

PLATE XI.—SULFUR PRINTS OF RIVET BARS OBTAINED FROM VARIOUS MANUFACTURERS. FULL SIZE.

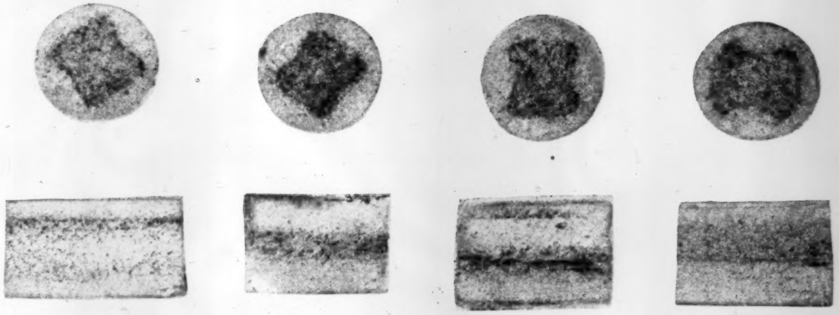

FIG. 32.—Manufacturer No. 4: S = 0.038. Second Print, 5-per-cent Acid, 5 min.

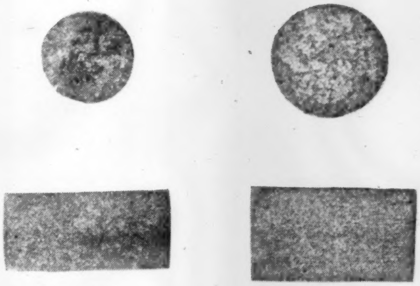

FIG. 33.—Manufacturer No. 5: S = 0.042.
Second Print, 5-per-cent Acid, 5 min.

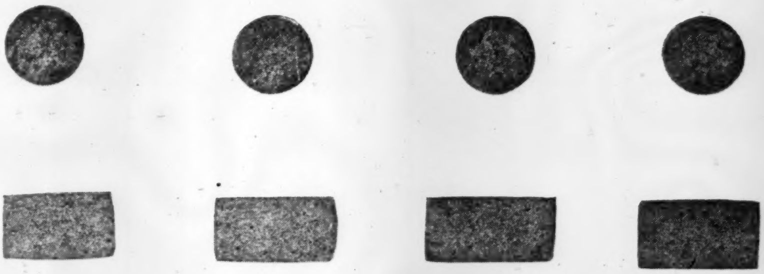

FIG. 34.—Manufacturer No. 6: S = 0.048. Second Print, 5-per-cent Acid, 4 min.

PLATE XII.—SULFUR PRINTS OF RIVET BARS OBTAINED FROM VARIOUS MANUFACTURERS. FULL SIZE.

reproduced in Plates I to V, inclusive. Bars of commercial rivet steel were treated in the same way. Photographs of sulfur prints of commercial rivet steel are shown in Plates XI and XII. For the investigation of slab material, a sulfur print was made of a full-size transverse section and a central longitudinal section of a slab from each heat. Photographs of these prints are reproduced in Plates VI to X, inclusive.

To make a sulfur print of a steel specimen, photographic printing paper is saturated with dilute acid and applied face down to a smooth surface of the steel. After making the print in this way it is fixed by "Hypo" solution. In making the sulfur prints of this material, a 5-per-cent aqueous solution of sulfuric acid was used in all the specimens except those from the three heats of highest sulfur percentage; in these three heats, 3-per-cent sulfuric acid was used. Several prints in rapid succession were made from each specimen. In some cases, the first print was the best; in most cases, however, the second print was the best. The data in regard to strength of acid, number of the print, and time of contact with the steel are given in Plates I to XII, inclusive. These data should be taken into account, in comparing the depth of shading of the prints.

Description of Macrostructure.—It was found difficult to obtain clear sulfur prints of some of the sections. With bars having low sulfur percentage it was especially difficult to obtain distinct patterns. Prints of some specimens having moderately high sulfur percentage also proved indistinct. If, however, a study be made of the prints of all the bars and slabs from each heat, definite conclusions can be drawn in regard to the macrostructure.

The specimens from heats *A*, *F* and *H*, having 0.028, 0.031 and 0.035 per cent of sulfur, respectively, as shown on Plate I, have outer layers of apparently higher sulfur percentage than the mottled cores. The same type of segregation is shown in the slabs of these heats as illustrated by Plate VI. Plate VI also shows on the sulfur prints of transverse sections thin layers, apparently having a high percentage of sulfur, surrounding the rectangular cores.

The specimens from heats *G*, *B* and *C*, having 0.036, 0.037 and 0.044 per cent sulfur, respectively, as shown on Plate II, have outer layers apparently having higher sulfur percentage than the cores. In some of these bars the core is surrounded by a thin adjacent narrow layer apparently having still higher sulfur percentage. In some bars, notably those of heat *C*, the core is square or rectangular. The slabs of these three heats, as shown on Plate VII, have irregular rectangular or elliptical cores. The elliptical core, Fig. 18, is surrounded by an adjacent narrow layer of apparently still lower sulfur content and this in turn by a layer of apparently higher sulfur content. Figs. 19 and 20 show also surrounding the rectangular core a thin layer of apparently high sulfur content.

The specimens from heats *J*, *K* and *D*, having 0.049, 0.058 and 0.060 per cent sulfur, respectively, as illustrated in Plate III, all apparently have outer layers of higher sulfur percentage than the core. In Figs. 7 and 9 each core appears irregular and mottled. In Fig. 8 each core is definitely square or rectangular and is surrounded by a thin layer of apparently high sulfur content. As shown in Plate VIII the slabs representing these three heats have light rectangular cores surrounded by dark layers. In Fig. 21, there is a thin intermediate black layer.

The specimens from heats *E*, *P* and *S*, having 0.060, 0.063 and 0.069 per cent sulfur, respectively, as illustrated in Plates IV and IX, all apparently show sulfur segregation similar to that found in the material previously described. A comparison of Fig. 10, Plate IV, and Fig. 24, Plate IX, shows that the light core is relatively large and that within this core there is mottled segregation of sulfur. Fig. 11 of Plate IV shows a definite light rectangular core surrounded by a darker layer. The same kind of segregation is visible in the slab of the same material shown in Fig. 25, Plate IX. Fig. 12 of Plate IV shows within the light cores smaller cores, either square or irregular in shape. The slab of the same material shown in Fig. 26, Plate IX, has surrounding the light core a thin layer made up of black spots.

The specimens from heat *R*, having 0.083 per cent of sulfur, is illustrated in Plates V and X. As shown in Fig. 13, Plate V, the light square core of these bars is so large that the corners are practically on the circumference of the bar. Within these cores are irregular light areas surrounded by a thin dark layer. The slab of this material, as shown in Fig. 27, Plate X, has a definite core approximately rectangular in shape.

Figs. 14 and 28, Plates V and X, show the sulfur distribution in the specimens from heat *M*, having 0.179 per cent of sulfur. The segregation in this material is similar to that found in heat *R*. In Fig. 28, Plate X, however, a thin dark layer is visible near the ends of the cross-section. This layer evidently continues along the surface of the flat sides of the slab.

The macrostructures found in the commercial rivet steel are illustrated in Plates XI and XII. The sulfur distribution in steels furnished by manufacturers Nos. 1, 2 and 6, in three of the bars furnished by manufacturer No. 3, and in one of the bars furnished by manufacturer No. 5, is apparently of the same general type as that found in the heats manufactured under the supervision of the Joint Committee. There is in each of these prints a light central core of varying shape surrounded by a layer of apparently much higher sulfur percentage; this in turn is surrounded in some cases by a layer, complete or incomplete, apparently having a sulfur percentage little if any higher than that of the core. In each of the bars furnished by manufacturer No. 4, however, in one of the bars furnished by manufacturer No. 3, and in one of the bars furnished by manufacturer No. 5, there is a core of apparently high sulfur percentage surrounded by a layer apparently having a much lower sulfur content.

The significance of the two general types of sulfur segregation found in the rivet steels above described will be discussed later.

Origin of the Cored Macrostructure and Causes of the Various Shapes of Core.—The cored structure evidently originated in the ingot from which these bars and slabs were made. Ingots of rectangular cross-section, such as those used in manufacture of the bars of rivet steel for the Joint Committee, would have rectangular cores. There is often in ingots a very sharp line of demarcation between the outer layer of columnar macrostructure and the core of irregular crystallin macrostructure. Since the ingots furnished for the Joint Committee were nearly square in cross-section (18 by 20 in.) the cores were evidently nearly square.

In rolling these ingots into billets the approximately square shape of the core was preserved in some billets; in other billets the core was distorted into a dumb-bell shape. In rolling the billets into round rods the change of section from square to round was in some cases accomplished by a lateral squeezing of the surface layer without much distortion of the square or rectangular or dumb-bell shape of the core. In other cases, as illustrated by Fig. 9 of Plate III, the original shape of the billet core has been obliterated. The cores of the slabs are usually nearly rectangular since the reduction in rolling was almost entirely in one direction.

Possible Causes of the Types of Segregation Apparently Indicated by the Sulfur Prints.—In a solidifying ingot the outer layer consists of crystal columns perpendicular to the walls and bottom of the ingot mold through which heat from the ingot is flowing. There is a temperature gradient from the walls to the axis of the ingot and it is in the direction of this gradient that the crystals grow. The inner end of each growing crystal column is at the freezing point of the adjacent portion of the liquid. In some ingots this columnar growth persists until the entire ingot is solid. In most ingots, however, columnar growth after a time ceases abruptly and crystals of random orientation form throughout the liquid core. In a solidified ingot, therefore, there is usually found a wall of columnar crystals surrounding a core of crystals of random orientation. The surface of demarcation between these two types of crystallization is distinct.

The reasons for this duplex crystallin structure have been discussed by Brearley[1] and by Howe.[2] Whether the cross-section of an ingot is entirely columnar or of duplex structure depends largely on the steepness of the temperature gradient. Brearley has shown in his experiments with ingots of wax that even when selective freezing is not present the ingot may be so cast as to have a core of random or "free" crystals. If an ingot of wax is cast cold the temperature gradient decreases as the columnar wall crystals grow until the liquid core, stirred by convection and the pouring process, is at practically uniform temperature throughout. When this condition is reached, "free" crystallization starts and a core of random orientation is formed.

Howe[2] has shown, however, that in steel ingots the composition gradient due to selective freezing has a great influence in causing "free" crystallization to start after columnar crystallization has progressed to a certain point. Due to selective freezing of crystals richer in iron, the liquid in contact with the advancing crystal wall is richer in carbon than the liquid at the axis. Corresponding to this composition gradient there is a freezing point gradient. As the wall of solid metal thickens the temperature gradient decreases and the composition gradient increases until the freezing point gradient exceeds the temperature gradient. At this point columnar crystallization abruptly ceases and free crystallization throughout the liquid core begins.

Concentration of sulfides as well as carbon is greatest at the inner surface of the advancing columnar wall. When free crystallization starts it diminishes diffusion of this segregate toward the axis. The tendency of the process of selective freezing of wall and core, therefore, is to cause concentration of sulfur, phosphorus and carbon in the core of the ingot and especially in the layer adjacent to the columnar wall.

The tendency of the selective freezing of steel in ingots, therefore, is to produce central segregation. The amount of the segregation, however, may be greatly varied. It has been shown by Talbot[1] and by Arnold and Bolsover[2] that complete deoxidation of steel by silicon or aluminum diminishes segregation. Talbot states that aluminum increases the rate of solidification and thus decreases segregation. Arnold and Bolsover account for the effect of aluminum in a different way which does not seem conclusive. Howe, in a number of articles and in his book on the Metallography of Steel and Cast Iron, explains the effect of complete deoxidation on segregation as due chiefly to the quieting of the steel in the mold. This results in "land locking" of portions of liquid segregate between the dendrites of the advancing columnar crystals, thus diminishing central segregation.

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[1] A. W. and H. Brearley, "Some Properties of Ingots," *Journal*, Iron and Steel Inst., No. II, p. 136 (1916).

[2] Discussion of paper by Brearley by H. M. Howe, *Journal*, Iron and Steel Inst., No. II, p. 181 (1916).

Under certain conditions and by special methods, concentration of carbon, sulfur and phosphorus in the core may be entirely prevented. It is even possible to produce ingot cores in which the concentration of "impurities" is less than in the columnar wall. Near the bottom of an ingot, for example, "negative segregation" is frequently observed. This is due to the fact that "free crystals" of relatively pure material forming throughout the liquid core settle to the bottom. A cross-section taken near the bottom of an ingot may, therefore, show a core having lower percentages of carbon and sulfur than the columnar wall. Stead[3] and Talbot[4] describe a process of squeezing out the remaining liquid from the ingot by lateral compression before solidification is complete. Ingots treated in this way have an outer layer of moderate sulfur content, a core of low sulfur content, and an intermediate layer of high sulfur content. Stead, Talbot, and Savage[5] all show sulfur prints illustrating the negative segregation produced by this process. Stead and Talbot also give results of chemical analyses confirming quantitatively the qualitative indications of their sulfur prints. These analyses indicate that in ingots that have received lateral compression before solidification is complete the sulfur percentage in the core may be only one-half to one-tenth that in the outer layer of the ingot.

Sulfur prints have been used by many investigators to show the distribution of sulfur throughout a section of steel. It has been assumed that such prints give reliable qualitative indications.

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[1] Benjamin Talbot, "Segregation in Steel Ingots," *Journal*, Iron and Steel Inst., No. II (1905).

[2] J. O. Arnold and G. R. Bolsover, "The Forms in Which Sulfides May Exist in Steel Ingots," *Journal*, Iron and Steel Inst., No. 1 (1914); "Supplementary Notes on the Forms in Which Sulfides May Exist in Steel Ingots," *Journal*, Iron and Steel Inst., No. 1 (1915).

[3] Discussion by J. E. Stead of paper by Hadfield, "On a New Method of Revealing Segregation in Steel Ingots," *Journal*, Iron and Steel Inst., No. II, p. 48 (1912).

[4] Benjamin Talbot, "On the Production of Sound Steel by Lateral Compression of the Ingot Whilst Its Center is Liquid," *Journal*, Iron and Steel Inst., No. I, p. 30 (1913).

[5] Discussion of paper by Talbot by H. Savage, *Journal*, Iron and Steel Inst., No. I, p. 59 (1913).

TABLE II.—COMPARISON OF SULFUR PERCENTAGES NEAR CENTER OF BAR WITH AVERAGE SULFUR PERCENTAGE IN ENTIRE CROSS-SECTION. SERIES A, GROUP I MATERIAL.

Heat Letter	Sulfur Print		Sulfur, per cent					
	Shown in	Relative Shade of Core	Analyses Previously Published[1]	N. E. S. Results, Entire Cross-Section[2]	N. E. S. Rechecks on Original Samples (April, 1924), Entire Cross-Section	Analyses of Drillings from Centers of Bar Sections		
						Diameter of Section Included, in.	First Results	Second Results
1	2	3	4	5	6	7	8	9
A	Plate I Fig. 1	light		0.030	0.032	$\frac{3}{8}$	0.036	0.030
				0.030	0.034		0.033	0.030
			0.028	Average 0.030	0.033		0.035	0.030
F	Plate I Fig. 2	light		0.030		$\frac{3}{8}$	0.045	.....
				0.031	.....		0.046	.....
			0.031	Average 0.031	.....		0.046	.....
H	Plate I Fig. 3	light		0.035	.....	$\frac{5}{16}$	0.038	.....
				0.035	.....		0.041	.....
			0.035	Average 0.035	.....		0.040	.....
G	Plate II Fig. 4	light		0.036	.....	$\frac{1}{4}$	0.045	.....
				0.036	.....		0.045	.....
			0.036	Average 0.036	.....		0.045	.....
B	Plate II Fig. 5	light		0.039	0.040	$\frac{3}{8}$	0.042	.....
				0.039	0.040		0.042	.....
			0.037	Average 0.039	0.040		0.042	.....
C	Plate II Fig. 6	light		0.047	0.049	$\frac{1}{4}$	0.053	.....
				0.047	.....		0.054	.....
			0.044	Average 0.047	0.049		0.054	.....
J	Plate III Fig. 7	light		0.049	.....	$\frac{3}{8}$	0.067	.....
				0.048	.....		0.070	.....
			0.049	Average 0.049	.....		0.069	.....
K	Plate III Fig. 8	light		0.059	.....	$\frac{1}{4}$	0.054	.....
				0.058	.....		0.054	.....
			0.058	Average 0.059	.....		0.054	.....
E	Plate III Fig. 9	light		0.066	0.065	$\frac{5}{16}$	0.063	.....
				0.065	0.066		0.063	.....
			0.060	Average 0.066	0.066		0.063	.....
D	Plate IV Fig. 10	light		0.063	.....	$\frac{9}{32}$	0.074	.....
				0.062	.....		0.074	.....
			0.060	Average 0.063	.....		0.074	.....
P	Plate IV Fig. 11	light		0.065	.....	$\frac{1}{4}$	0.064	.....
				0.065	.....		0.067	.....
			0.063	Average 0.065	.....		0.066	.....
S	Plate IV Fig. 12	light		0.074	.....	$\frac{3}{8}$	0.079	.....
				0.074	.....		0.079	.....
			0.069	Average 0.074	.....		0.079	.....
R	Plate V Fig. 13	light		0.086	0.093	$\frac{1}{4}$	0.082	.....
				0.085	0.093		0.082	.....
			0.083	Average 0.086	0.093		0.082	.....
M	Plate V Fig. 14	light		0.183	0.193	$\frac{5}{16}$	0.193	0.193
				0.181	0.195		0.198	0.195
			0.179	Average 0.182	0.194		0.196	0.194

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[1] Average of Watertown Arsenal and Naval Experiment Station results, First Report of Joint Committee. See Table I.

[2] Naval Experiment Station results which averaged with Watertown Arsenal results gave the values recorded in column 4.

The evidence obtained by means of sulfur prints in this investigation would seem to indicate, therefore, that in the heats of steel manufactured for the Joint Committee there is "negative segregation" of sulfur. All the bars and slabs of this material gave sulfur prints showing a light core surrounded by a darker layer. Most of the sulfur prints show also an intermediate layer of still darker shade. Many of the sulfur prints resemble greatly the prints shown by Stead, Talbot, and Savage. Of the commercial rivet steel bars examined, fifteen gave sulfur prints with light core and six gave prints with dark core. Evidence obtained from sulfur prints, therefore, would indicate that the negative type of segregation corresponds to the usual commercial practice in the manufacture of rivet steel.

TABLE III.—COMPARISON OF SULFUR PERCENTAGES NEAR CENTER OF BAR WITH AVERAGE SULFUR PERCENTAGE IN ENTIRE CROSS-SECTION. COMMERCIAL RIVET STEELS.

Manufacturer No.	Sulfur Print		Sulfur, per cent		
			Naval Experiment Station Results, Entire Cross-Section	Analyses of Drillings from Centers of Bar Sections	
	Shown in	Relative Shade of Core		Diameter of Section Included, in.	Results
1	2	3	4	5	6
1	Plate XI Fig. 29	light	0.029 0.028	$\frac{1}{4}$	0.031 0.031
			Average 0.029		0.031
2	Plate XI Fig. 30	light	0.033 0.033	$\frac{3}{8}$	0.026 0.026
			Average 0.033		0.026
3	Plate XI Fig. 31	dark	0.040 0.041	$\frac{3}{8}$	0.043 0.044
	First print[1]		Average 0.041		0.044
3	Plate XI Fig. 31	light	0.040 0.041	$\frac{3}{8}$	0.035 0.036
	Third print[1]		Average 0.041		0.036
4	Plate XII Fig. 32	dark	0.048 0.047	$\frac{1}{4}$	0.071 0.071
			Average 0.048		0.071
5	Plate XII Fig. 33 First print[1]	dark	.... 0.046	$\frac{3}{16}$	.... 0.063
5	Plate XII Fig. 33	light	....	$\frac{1}{4}$	0.042 0.043
	Second print[1]		0.050		0.043

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[1] Print of transverse section counting from left to right.

If the negative segregation indicated by sulfur prints actually exists, it could be due either to natural negative segregation caused by settling of free crystals during solidification of the core, or artificial negative segregation caused by compression of the ingot before complete solidification. It would not be expected that natural negative segregation would be found in all the bars and slabs examined, since these were made from billets comprising sixty per cent of the ingot. The artificial type of negative segregation also would not be expected in bars made from ingots that had become cold. And yet *all* the bars and slabs manufactured for the Joint Committee give sulfur prints apparently indicating negative segregation.

Investigation of Sulfur Segregation by Chemical Analysis.—Since the tension, shear and impact specimens and a large proportion of the torsion specimens consisted of core material, it was evidently important to determine quantitatively the segregation in this material. For this reason, chemical samples were taken from the cores of representative bars. Care was taken to include in each sample only the portions of each core that give a relatively light or dark area on the sulfur print. Results of chemical analyses are given in Tables II and III in comparison with results previously obtained on samples representing entire cross-sections.

Results obtained with samples from the heats of steel manufactured for the Joint Committee are given in Table II. A comparison of columns 8 and 5 of this table shows that the negative segregation apparently indicated by the sulfur prints does not exist. In nearly all the bars the core contains a slightly higher percentage of sulfur than the average of the entire bar. In a few bars the percentage of sulfur found in core and entire bar are practically the same. In column 6 of the table there are listed check analyses obtained with original samples that were used for the analyses for the First Report of the Joint Committee. The results obtained by these check analyses agree fairly well with the results given in column 5, except in the case of the material of highest sulfur content, heat M, for which somewhat higher results were obtained than those given in the First Report of the Joint Committee. Evidently, however, there is no important segregation, either positive or negative, in the bars from these fourteen heats.

Results of analyses of the commercial steels are given in Table III. Volumetric results obtained with core samples and with samples from entire cross-sections are given in columns 6 and 4, respectively. Comparison of these two columns will show that in five of the seven bars there is little or no central segregation. In two of the bars there is decided central segregation. These two bars, and one bar that shows very slight central segregation, are the only ones that show dark cores in the sulfur prints.

Evidently, therefore, the sulfur print does not always give a reliable indication of even the qualitative distribution of sulfur in a section of steel. When there is a sharp line of demarcation between two areas in a sulfur print, the indications as regards sulfur segregation should always be checked by chemical analyses. Such checking is especially necessary when the sulfur print shows a light core.

The core, originating from the relatively fine, random crystals of the ingot, evidently liberates its sulfur under attack of acids less readily than does the outer layer of the bar that has originated from the columnar crystals. It is well known that of two pieces of steel having approximately the same composition one may give a darker sulfur print than the other, under the same conditions. In each of the bars and slabs under consideration the core and case behave as differently, in the formation of sulfur prints, as if they were from different pieces of steel. This difference in susceptibility to attack by dilute acids evidently accounts for the light sulfur print cores obtained with bars of Series A, Group I.

The facts brought out by the macroscopic examination show clearly that such an investigation should have been completed before chemical samples were taken and that both macroscopic and chemical examination should have been completed before specimens were cut for microscopic examination and physical tests. Unfortunately it was not practicable to proceed in this order. It is necessary to carry on the various divisions of this work along with a great variety of other work in the two laboratories where the tests are being made and in the order determined by opportunity.

INVESTIGATION OF NON-METALLIC INCLUSIONS

Since the investigation of non-metallic inclusions was started at the same time as the investigation of macrostructure, it was not possible to take advantage of the information gained by the macroscopic examination. The sections examined were longitudinal surfaces of Charpy impact specimens or similar specimens so located with reference to the original bar that the area examined was about halfway between the center and circumference. Only bar material has been investigated for inclusions; no tests were made on specimens from slabs.

In preparing the surfaces for examination, great care was necessary to avoid as far as possible pitting of the soft metal, especially around small inclusions. The two final stages of the preparation consisted in polishing with two grades of alumina that would stay suspended in a vessel of water about 8 in. deep for 40 minutes and 3 hours, respectively.

A photomicrograph at a magnification of 100 was made on an 8 by 10-in. plate of a specimen from each bar. A 16-mm. apochromatic objective and a × 10 eye piece were used.

For comparison of the results obtained with the different heats, a method of making "composite" photomicrographs was developed. In this method four of the above described individual negatives, each representing one of the bars of a heat, were used successively to make one composite print to represent the heat. It is believed that the use of such composite photomicrographs gives a much better comparison between the heats than would be possible with use of individual photomicrographs alone.

Since the 8 by 10-in. photomicrographs, if published, would make the report too bulky, strips from each of the "composites" and from some representative individual photomicrographs have been cut and assembled for publication in Plates XIII to XVIII, inclusive. Plates XIII and XIV show composite photomicrographs from the fourteen heats manufactured for the Joint Committee, arranged in order of sulfur percentage. Plate XV shows composite photomicrographs of the bars of commercial steel obtained from various manufacturers. For comparison there is also included another composite area representing heat *M*. Typical samples of the individual photomicrographs from which these composites were made are shown in Plates XVI to XVIII, inclusive.

A casual comparison of the composite photomicrographs of Plates XIII and XIV to determine the relative quantity of inclusions in the various heats of steel shows that the order of increasing quantity of inclusions is not the same as the order of increasing sulfur percentage. These fourteen heats, however, may be divided as regards quantity of inclusions roughly into two groups, corresponding to low sulfur and high sulfur. For example, it is apparent that in general the photomicrographs of Plate XIV show a much larger quantity of inclusions than those of Plate XIII. The photomicrographs of commercial steel, Plate XV, show a much larger quantity of inclusions in proportion to their sulfur content than do the photomicrographs of steel manufactured for the Joint Committee.

To obtain a more exact comparison of the different heats of steel, four independent observers, without knowledge of the sulfur percentages, were asked to arrange the photomicrographic strips in

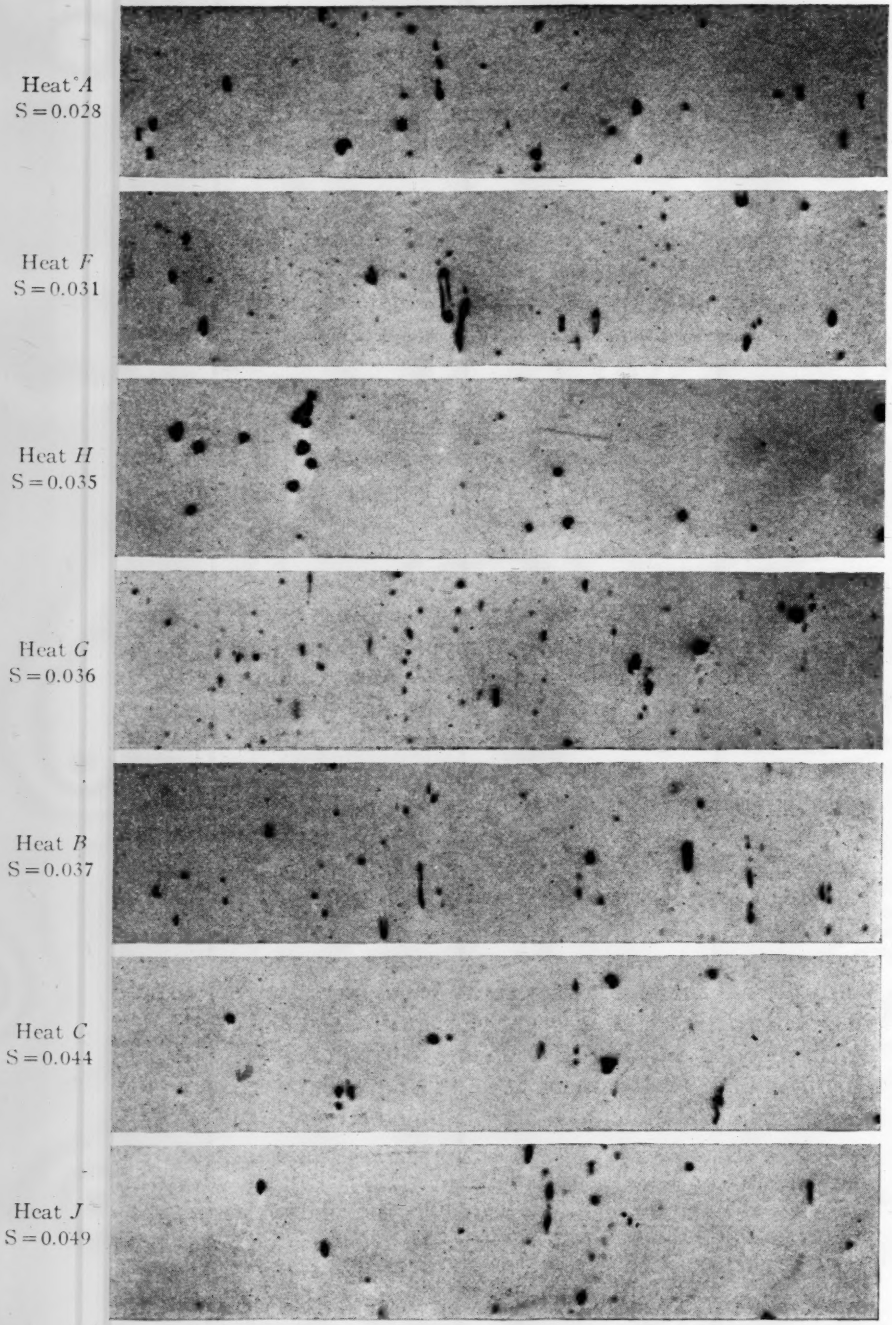

Heat A
S = 0.028
Heat F
S = 0.031
Heat H
S = 0.035
Heat G
S = 0.036
Heat B
S = 0.037
Heat C
S = 0.044
Heat J
S = 0.049

PLATE XIII.—COMPOSITE PHOTOMICROGRAPHS SHOWING NON-METALLIC INCLUSIONS IN RIVET STEEL (× 100).

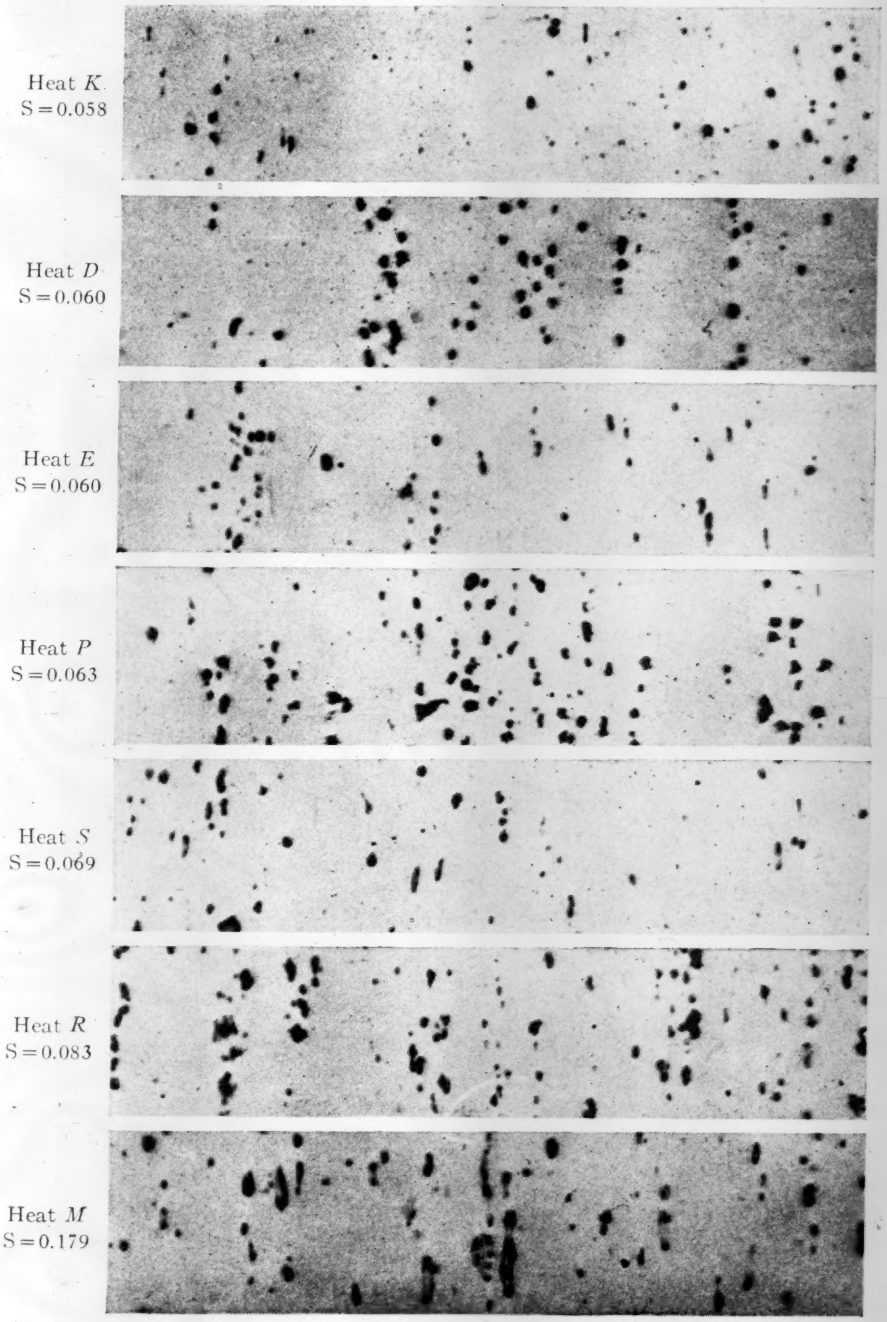

Heat *K*
S=0.058
Heat *D*
S=0.060
Heat *E*
S=0.060
Heat *P*
S=0.063
Heat *S*
S=0.069
Heat *R*
S=0.083
Heat *M*
S=0.179

PLATE XIV.—COMPOSITE PHOTOMICROGRAPHS SHOWING NON-METALLIC INCLUSIONS IN RIVET STEEL (× 100).

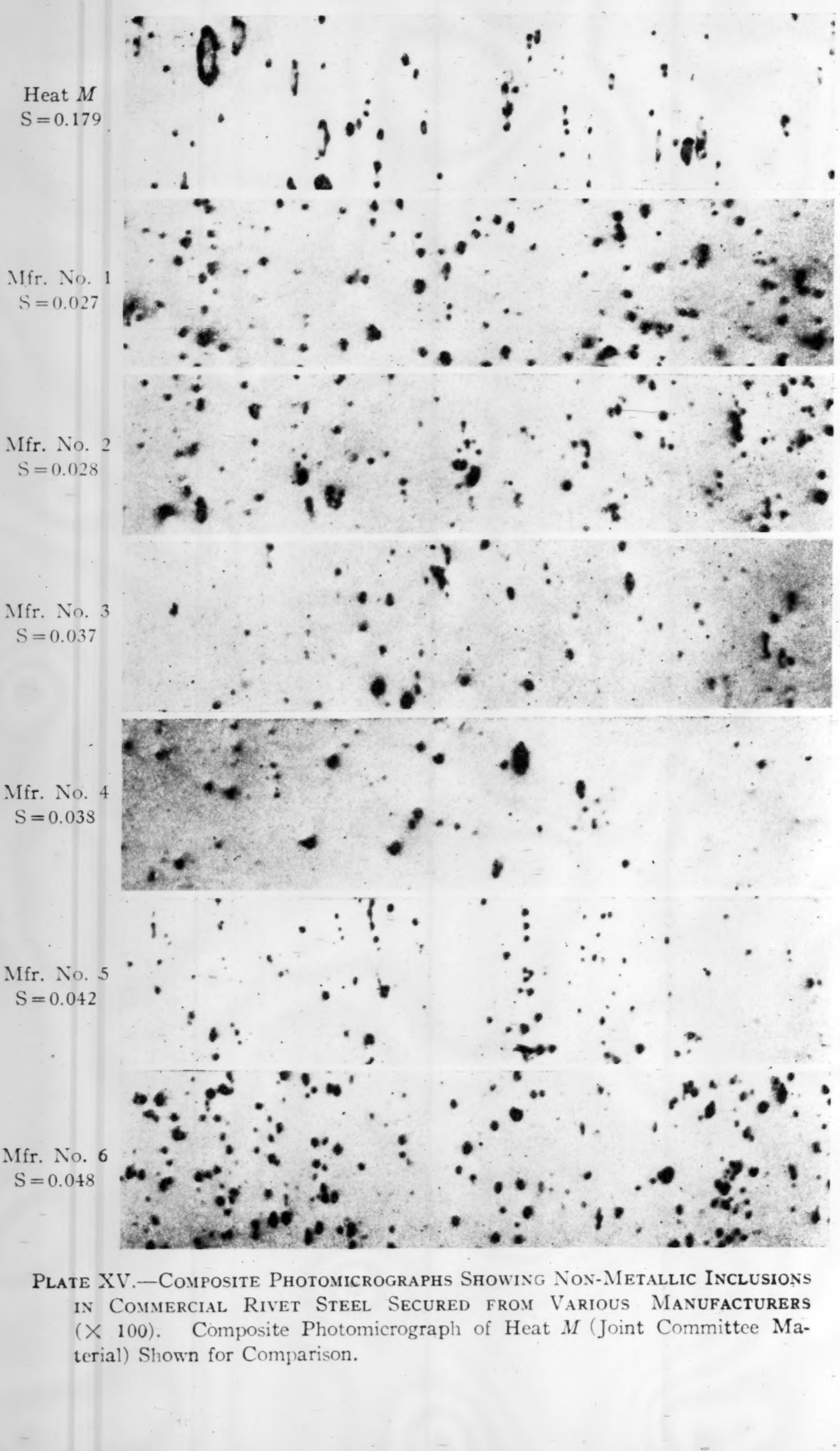
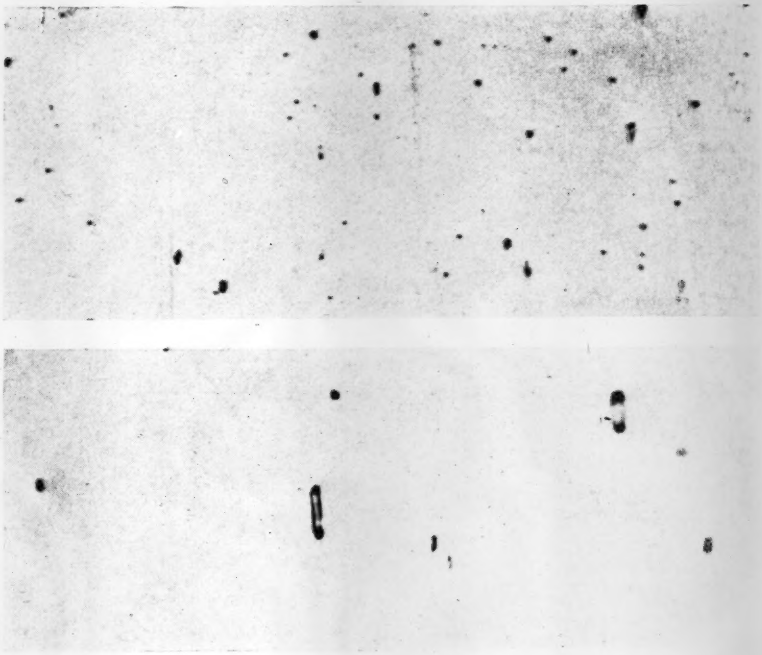
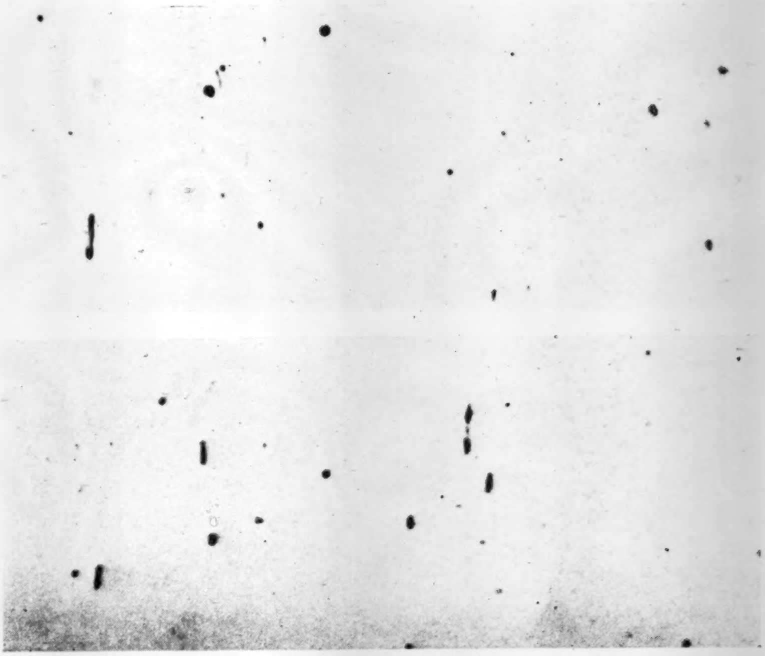

Heat *M*
S=0.179
Mfr. No. 1
S=0.027
Mfr. No. 2
S=0.028
Mfr. No. 3
S=0.037
Mfr. No. 4
S=0.038
Mfr. No. 5
S=0.042
Mfr. No. 6
S=0.048

Plate XV.—Composite Photomicrographs Showing Non-Metallic Inclusions in Commercial Rivet Steel Secured from Various Manufacturers (× 100). Composite Photomicrograph of Heat *M* (Joint Committee Material) Shown for Comparison.

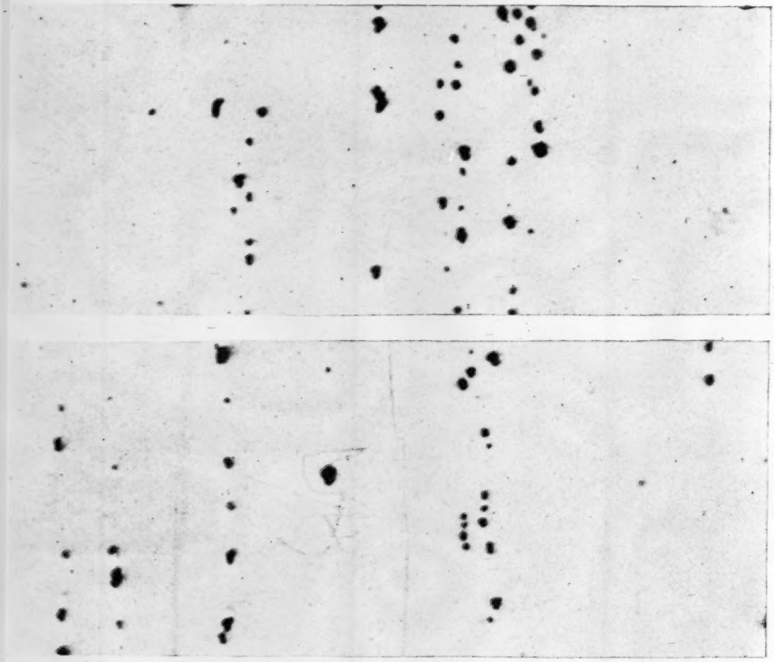


Heat *F*
S = 0.031

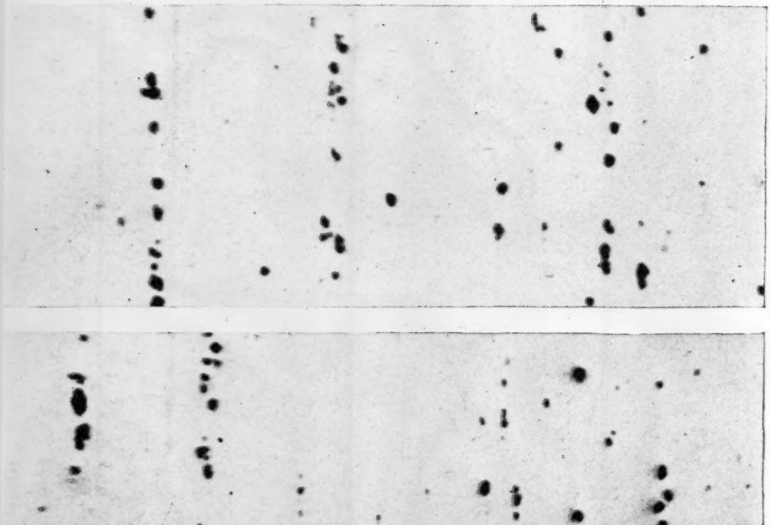


Heat *J*
S = 0.049

PLATE XVI.—TYPICAL INDIVIDUAL PHOTOMICROGRAPHS SHOWING NON-METALLIC INCLUSIONS IN RIVET STEEL FROM WHICH COMPOSITES WERE MADE (× 100).

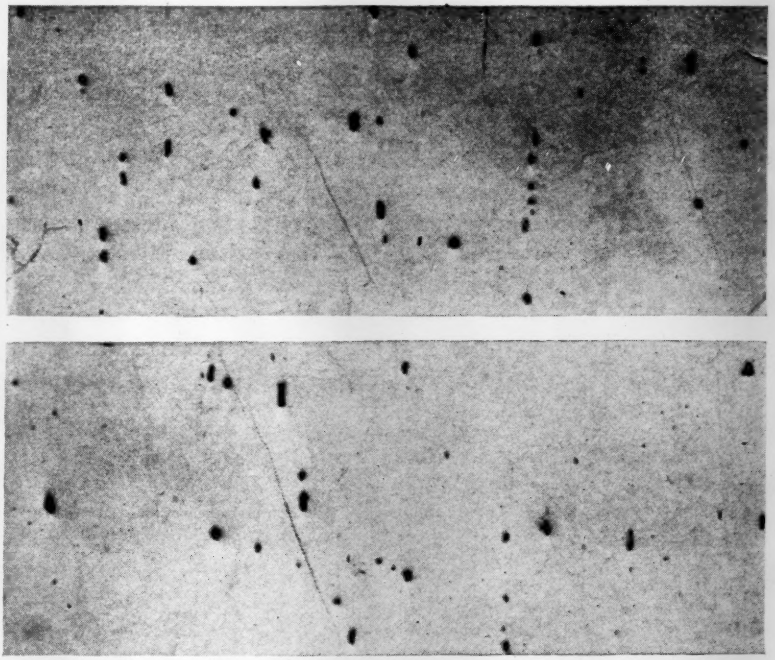


Heat *D*
S = 0.060

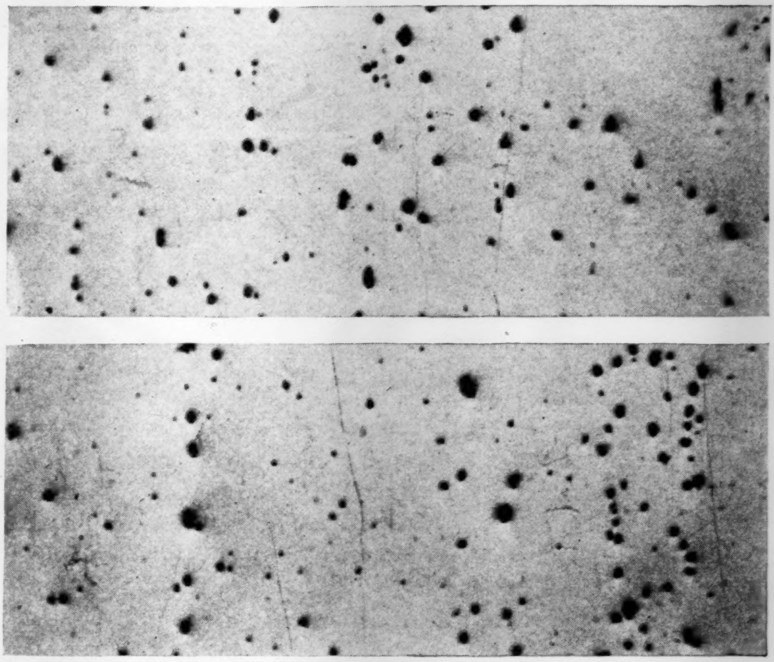


Heat *R*
S = 0.083

PLATE XVII.—TYPICAL INDIVIDUAL PHOTOMICROGRAPHS SHOWING NON-METALLIC INCLUSIONS IN RIVET STEEL FROM WHICH COMPOSITES WERE MADE (× 100).



Mfr. No. 3
S = 0.037



Mfr. No. 6
S = 0.048

PLATE XVIII.—TYPICAL INDIVIDUAL PHOTOMICROGRAPHS SHOWING MON-METALLIC INCLUSIONS IN COMMERCIAL MATERIAL FROM WHICH COMPOSITES WERE MADE (× 100).

order of increasing quantity of inclusions. From the results of this grading, as given in Table IV, it will be seen that the heats are not graded according to sulfur content. The heats of highest sulfur percentages, however, have consistently been placed at the proper end of the list. A similar grading was obtained with the full-size photomicrographs.

Evidently, therefore, inclusions other than sulfides constitute an important proportion of the total quantity of inclusions. With increase in sulfur content, the proportion of inclusions other than sulfides decreases. In the material of high sulfur percentage, consequently, the grading according to quantity of inclusions corresponds more closely to the order of sulfur percentage.

TABLE IV.—RESULTS OF COMPARISON BY FOUR INDEPENDENT OBSERVERS OF THE "COMPOSITE" STRIP PHOTOMICROGRAPHS, PLATES XIII TO XV, INCLUSIVE, REPRESENTING NON-METALLIC INCLUSIONS.

The steels are arranged in order of increasing quantity of inclusions, reading downward, as reported by the respective observers.

Observer A				Observer B				Observer C				Observer D			
Joint Committee Material		Commercial Material		Joint Committee Material		Commercial Material		Joint Committee Material		Commercial Material		Joint Committee Material		Commercial Material	
Heat	Sulfur, per cent	Mfgr. No.	Sulfur, per cent	Heat	Sulfur, per cent	Mfgr. No.	Sulfur, per cent	Heat	Sulfur, per cent	Mfgr. No.	Sulfur, per cent	Heat	Sulfur, per cent	Mfgr. No.	Sulfur, per cent
C	0.044	..	..	H	0.035	..	..	C	0.044	..	..	C	0.044	..	..
H	0.035	..	..	C	0.044	..	..	H	0.035	..	..	H	0.035	..	..
J	0.049	..	..	J	0.049	..	..	J	0.049	..	..	J	0.049	..	..
F	0.031	..	..	F	0.031	..	..	B	0.037	..	..	B	0.037	..	..
B	0.037	..	..	B	0.037	..	..	A	0.028	..	..	F	0.031	..	..
A	0.028	..	..	A	0.028	..	..	F	0.031	..	..	A	0.028	..	..
G	0.036	..	..	K	0.058	..	..	S	0.069	..	..	K	0.058	..	..
K	0.058	..	..	S	0.069	4	0.038	K	0.058	..	..	E	0.060	4	0.038
		3	0.037												
S	0.069	4	0.038	E	0.060	3	0.037	G	0.036	..	..	G	0.036	..	..
E	0.060	5	0.042	G	0.035	5	0.042	E	0.060	4	0.038	S	0.069	3	0.037
D	0.060	2	0.028	M	0.179	..	..	M	0.179	3	0.037	M	0.179	5	0.042
M	0.179	..	..	D	0.060	2	0.028	D	0.060	5	0.042	D	0.060	..	..
R	0.083	1	0.027	R	0.083	..	..	R	0.083	2	0.028	R	0.083	2	0.028
						1	0.027			1	0.027			1	0.027
P	0.063	6	0.048	P	0.063	6	0.048	P	0.063	6	0.048	P	0.063	6	0.048

At least two types of inclusions are prominent in this material, the well-known elongated manganese-sulfide particles appearing gray under the microscope, and apparently round inclusions occurring in streaks or irregular groups. The latter type of inclusions have been described by Comstock.[1] He showed that inclusions such as those would be due to particles of alumina resulting from the use of aluminum as deoxidant in the steel-making process. A few specimens of these steels were sent to Mr. Comstock and he unhesitatingly states that they contain a considerable quantity of alumina. Due to lack of time an intensive study has not been made of the constitution of the inclusions in these heats of steel. There is given below, however, the amount of aluminum added in the manufacture of these steels taken from the original mill records furnished to the Joint Committee when the steel was made. The steels are arranged in order of increasing sulfur.

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[1] G. F. Comstock, "Alumina in Steel," *Chemical and Metallurgical Engineering*, December 1, 1915.

HEAT	SULFUR PER CENT	ALUMINUM ADDED IN MANUFACTURE, OZ. PER TON
A	0.028	4.2
F	0.031	3.4
H	0.035	4.5
G	0.036	3.4
B	0.037	4.0
C	0.044	Not recorded
J	0.049	5.1
K	0.058	5.4
D	0.060	4.4
E	0.060	3.6
P	0.063	5.1
S	0.069	Not recorded
R	0.083	Not recorded
M	0.179	3.4

The amount of aluminum added is representative of the usual practice and would not be considered excessive. There is, moreover, no discernible relation between the amounts of aluminum added and the number of inclusions shown in Plates XIII and XIV. Thus, if the heats are arranged in the order of increasing aluminum additions there is no concordance with the order in which the heats were arranged according to number of inclusions by the several observers, as recorded in Table II.

Any direct effect of sulfur on the physical properties of steel is probably due to the influence of manganese sulfide inclusions. Since these inclusions constitute only part of the total quantity of nonmetallic inclusions, their effect on the physical properties of rivet steel is obscured by the effect of inclusions of other kinds. This is especially true of steel having a low percentage of sulfur. The indirect effect of residual sulfur will be discussed later.

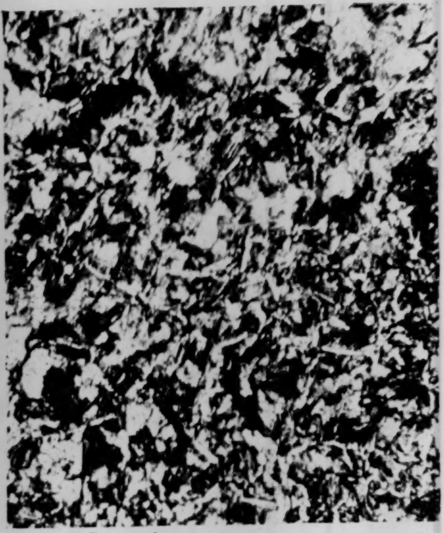
INVESTIGATION OF MICROSTRUCTURE

In starting the investigation of microstructure it appeared probable that the metallographic examination of etched specimens and the selection of representative specimens to illustrate the microstructure of this material would be simple. Since the carbon and manganese percentages do not differ greatly among the various heats, it even appeared probable that a single specimen each to represent material as rolled, annealed, and quenched, would be sufficient. It was soon found, however, that there were decided differences among the specimens of various sulfur percentages that had received the same heat treatment. In general it may be said that the microstructure appeared to vary directly with the percentage of sulfur. In comparing the various quenched specimens, for example, the impression obtained was as if they were steels that had been cooled through the critical range at rates that were slower the higher the percentage of sulfur.

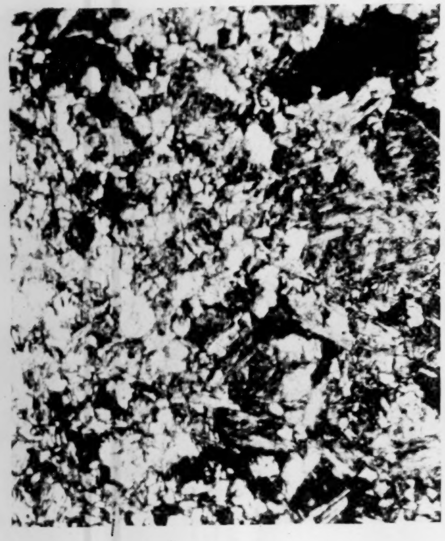
To make sure that these differences in microstructures were not due to slight differences in heat treatment, four specimens were cut from a bar representing each heat. These four sets were placed in the same furnace, heated above the critical range, and cooled at four different rates. One set was quenched in water, another was quenched in oil, and the third and fourth sets were cooled in air and in the furnace, respectively. Later another set was heated above the critical range and quenched in iced brine. Other sets were cooled through the critical range at various rates by air blast. The results of the metallographic examination of these sets of specimens may be summarized by the statement that each set showed the above described variation of microstructure with percentage of sulfur.

Investigation at Magnification of 100.—Four sets of specimens that were cooled through the critical range at various rates are shown in Plates XIX to XXII, inclusive. Plate XIX shows the microstructure of the specimens that were quenched in water. Though the variation in microstructure between adjacent photomicrographs from left to right in this plate is somewhat irregular, the general variation throughout the plate seems to be from a coarse network structure to a finer network and thence to a granular structure. The same kind of variation is more conspicuous in the oil-quenched specimens shown in Plate XX. In the oil-quenched specimens having 0.044 per cent sulfur or less the network structure predominates; in those having 0.049 per cent sulfur or more the granular structure predominates.

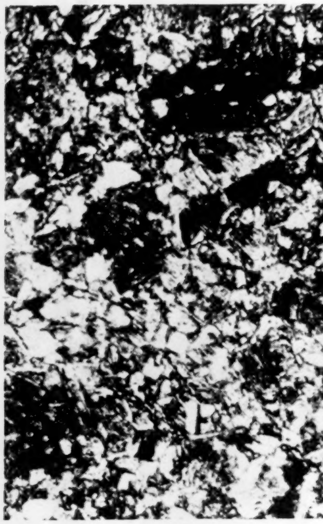
Photomicrographs at magnification of 100 of the specimens that were quenched in iced brine or cooled in air blast are not included in this report. The specimens that were quenched in iced brine show the same kind of variation of structure with sulfur content that is shown in the water-quenched specimens. In a set of specimens that were cooled in air blast to blackness in 14 seconds, the coarse net-



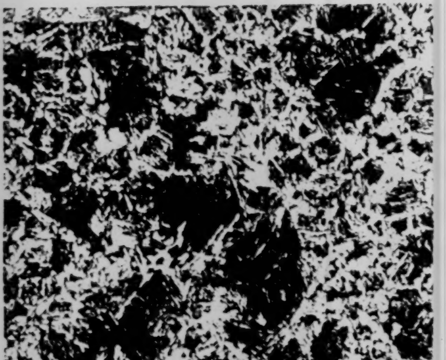
Heat *A:* S = 0.028



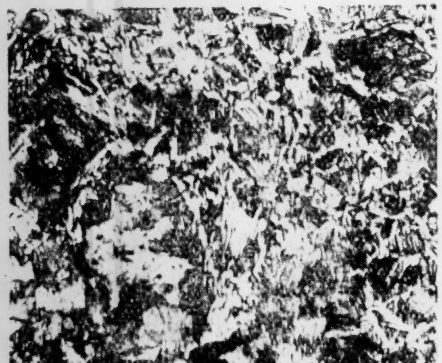
Heat *F:* S = 0.031



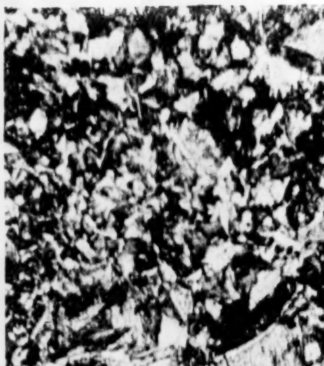
Heat *H:* S = 0.035



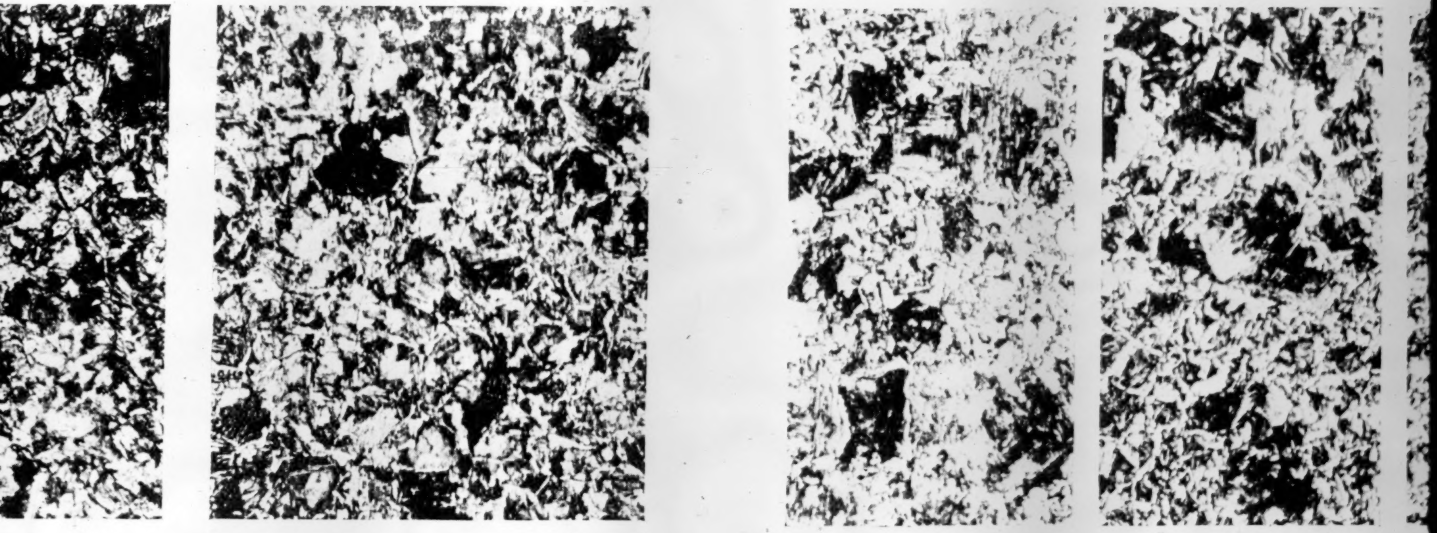
Heat *A:* S = 0.028



Heat *F:* S = 0.031



Heat *H:* S = 0.035



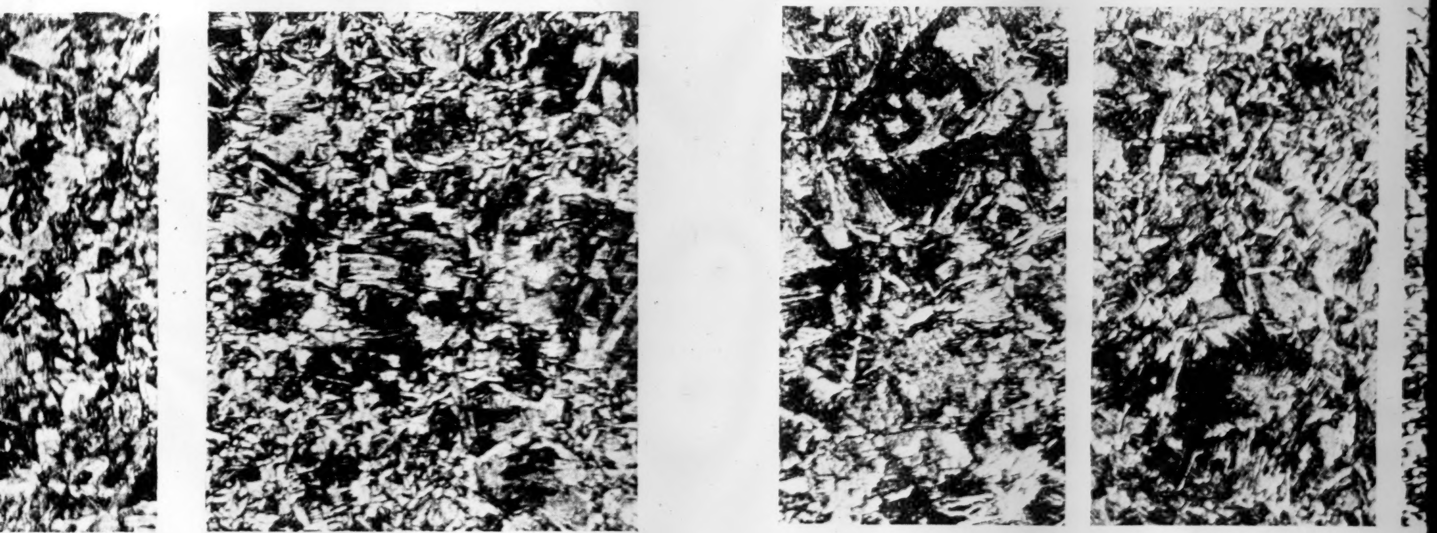
0.035

Heat *G:* S = 0.036

Heat *B:* S = 0.037

Heat *C:* S = 0.044

PLATE XIX.—PHOTOMICROGRAPHS OF FOURTEEN HEATS OF RIVET STEEL. SPECIMENS HEATED AB



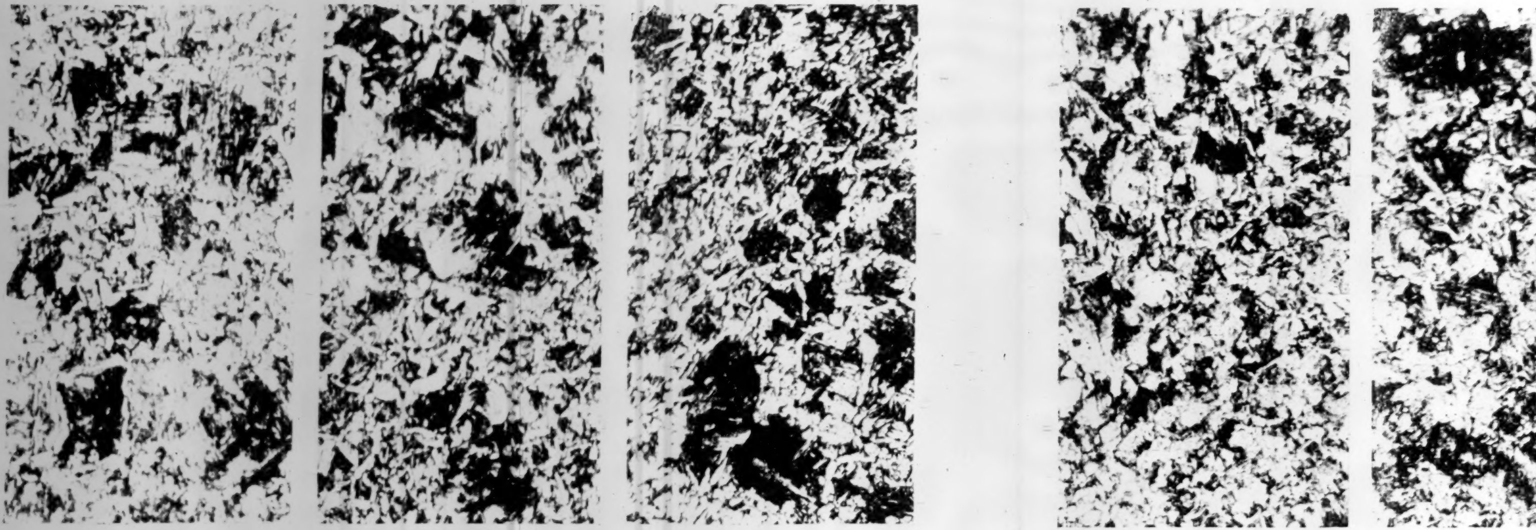
0.035

Heat *G:* S = 0.036

Heat *B:* S = 0.037

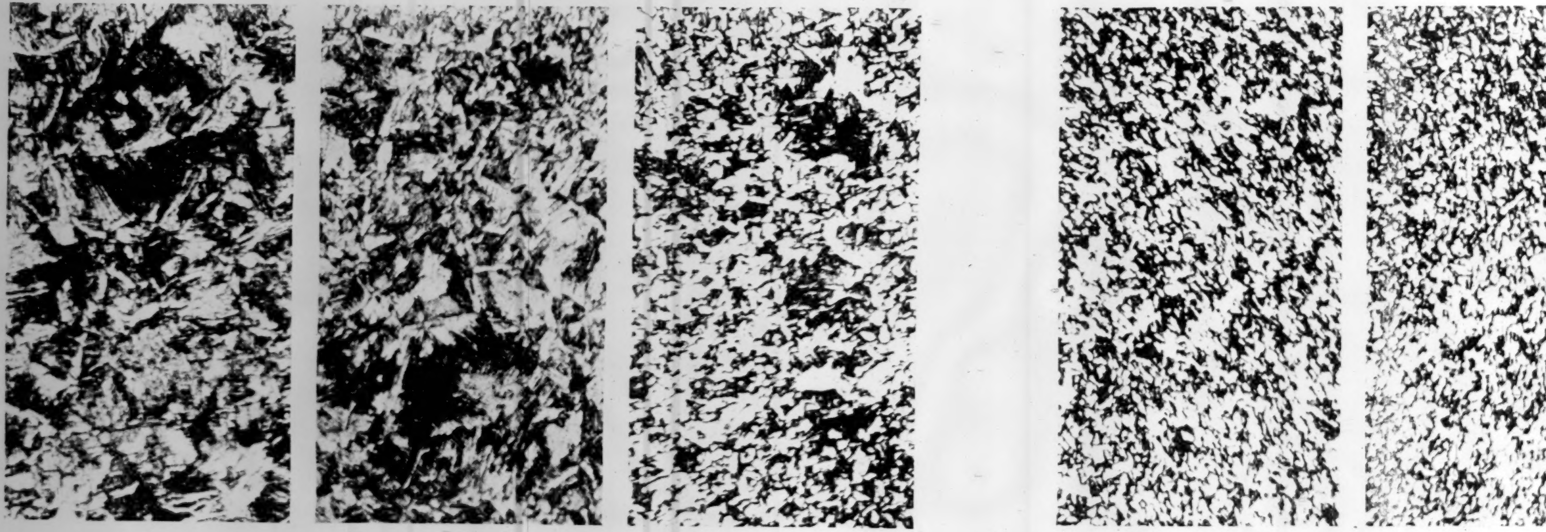
Heat *C:* S = 0.044

PLATE XX.—PHOTOMICROGRAPHS OF FOURTEEN HEATS OF RIVET STEEL. SPECIMENS HEATED A



Heat *B:* S = 0.037 Heat *C:* S = 0.044 Heat *J:* S = 0.049 Heat *K:* S = 0.058 Heat *D:* S

RAPHS OF FOURTEEN HEATS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 100).



Heat *B:* S = 0.037 Heat *C:* S = 0.044 Heat *J:* S = 0.049 Heat *K:* S = 0.058 Heat *D:* S =

RAPHS OF FOURTEEN HEATS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 100).

PLATES XIX, XX
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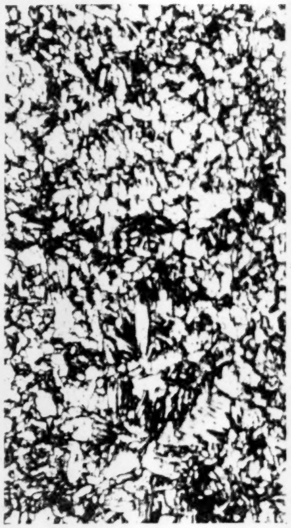
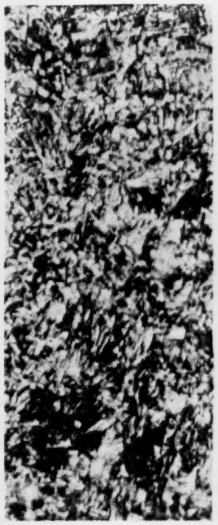
: S = 0.060

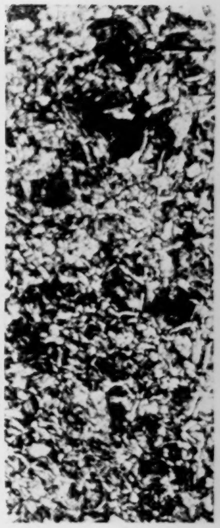


Heat *E:* S = 0.060

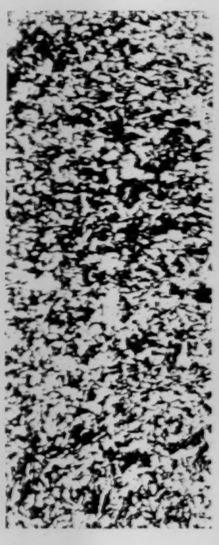


Heat *P:* S = 0.063

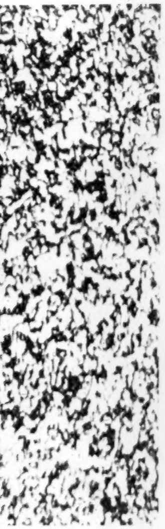
Heat *S:* S = 0.069



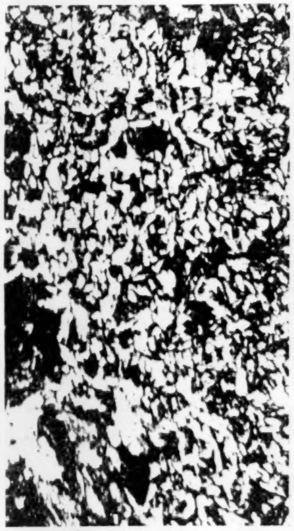
Heat *R:* S = 0.083



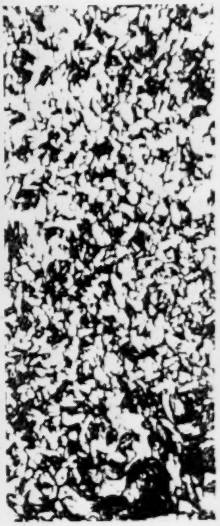
Heat *M:* S = 0.179



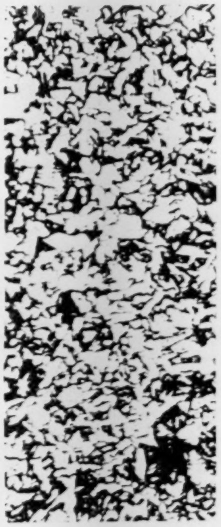
S = 0.060



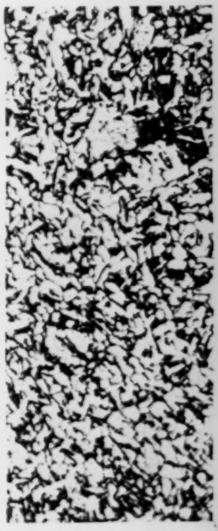
Heat *E:* S = 0.060



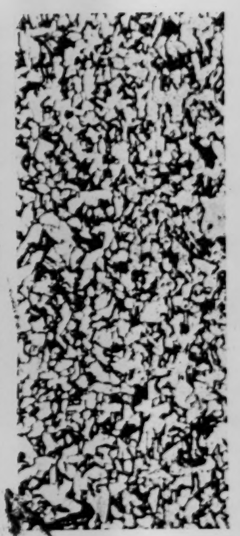
Heat *P:* S = 0.063



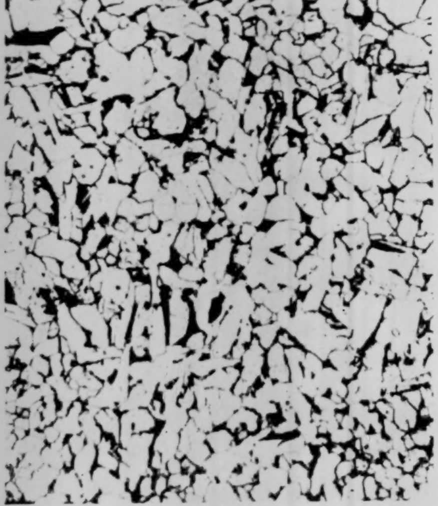
Heat *S:* S = 0.069



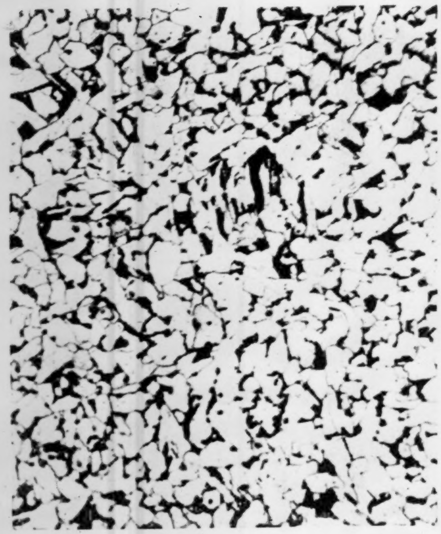
Heat *R:* S = 0.083



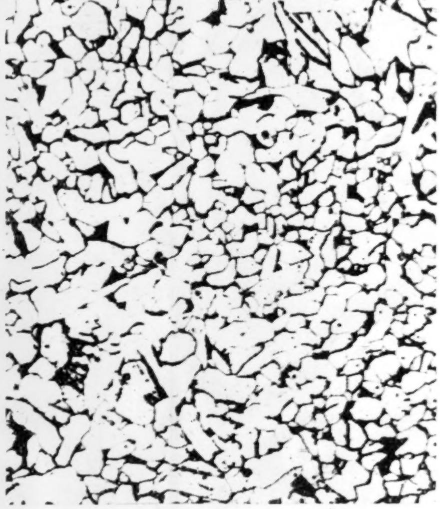
Heat *M:* S = 0.179



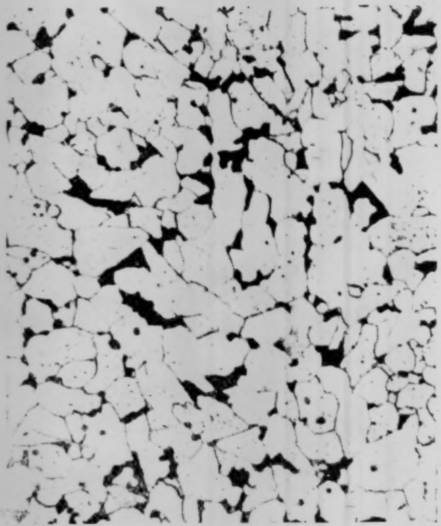
Heat *A:* S = 0.028



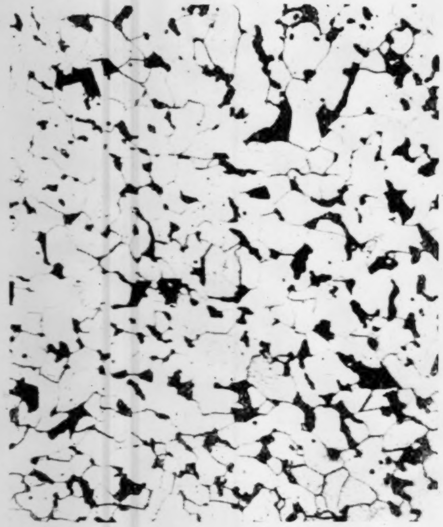
Heat *F:* S = 0.031



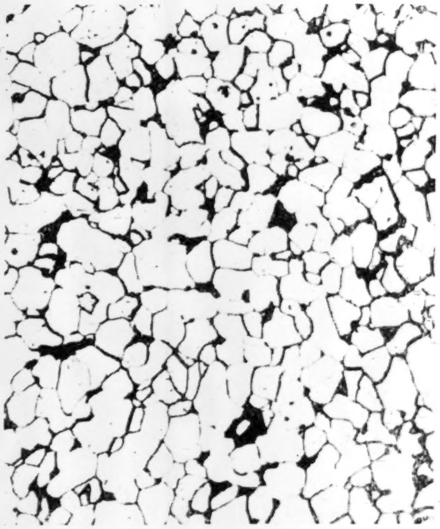
Heat *H:* S = 0.035



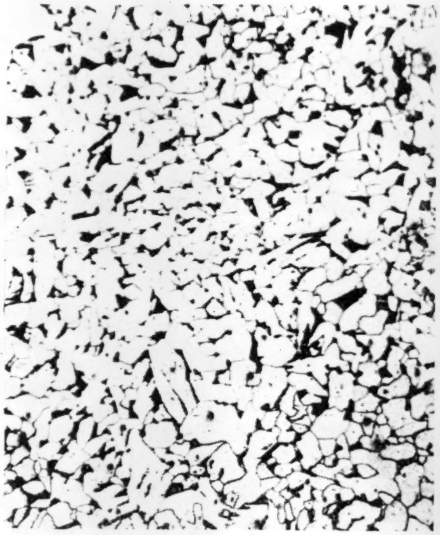
Heat *A:* S = 0.028



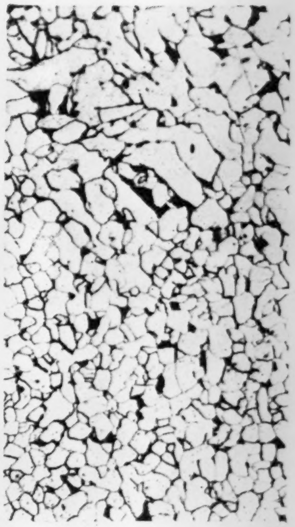
Heat *F:* S = 0.031



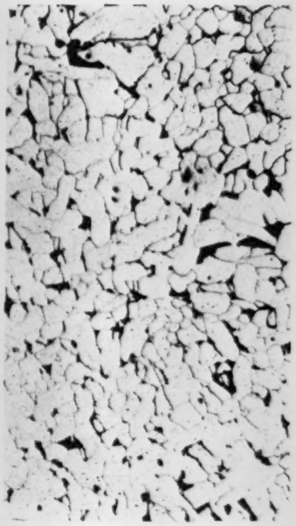
Heat *H:* S = 0.035



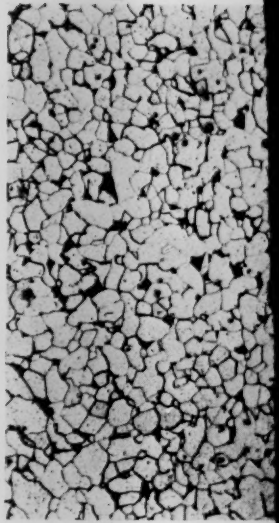
Heat *G:* S = 0.036



Heat *B:* S = 0.037

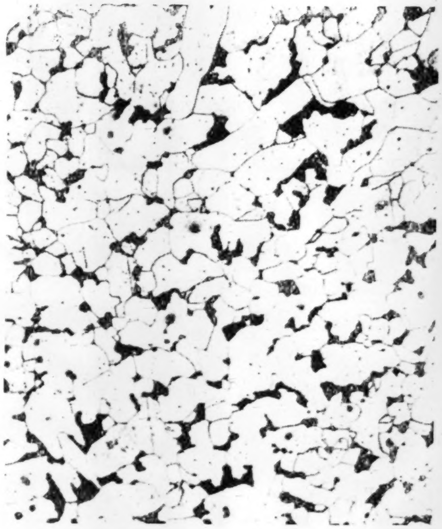


Heat *C:* S = 0.044

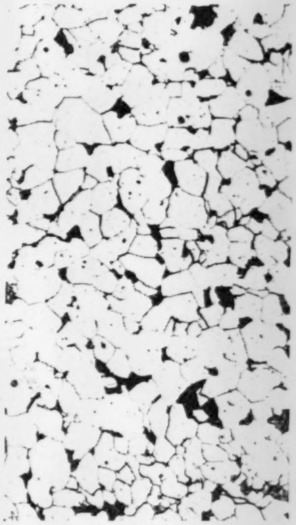


Heat *J:* S = 0.049

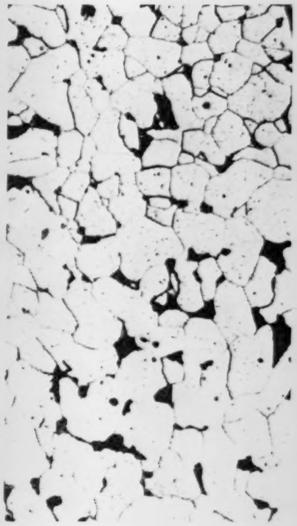
Plate XXI.—Photomicrographs of Fourteen Heats of Rivet Steel. Specimens Heated above the Critical Ra



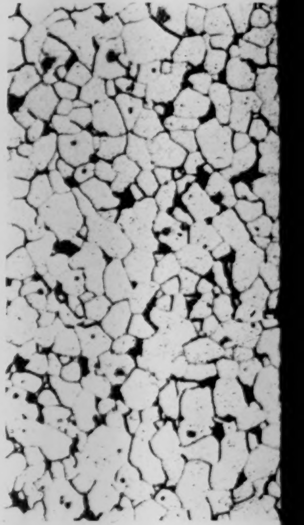
Heat *G:* S = 0.036



Heat *B:* S = 0.037

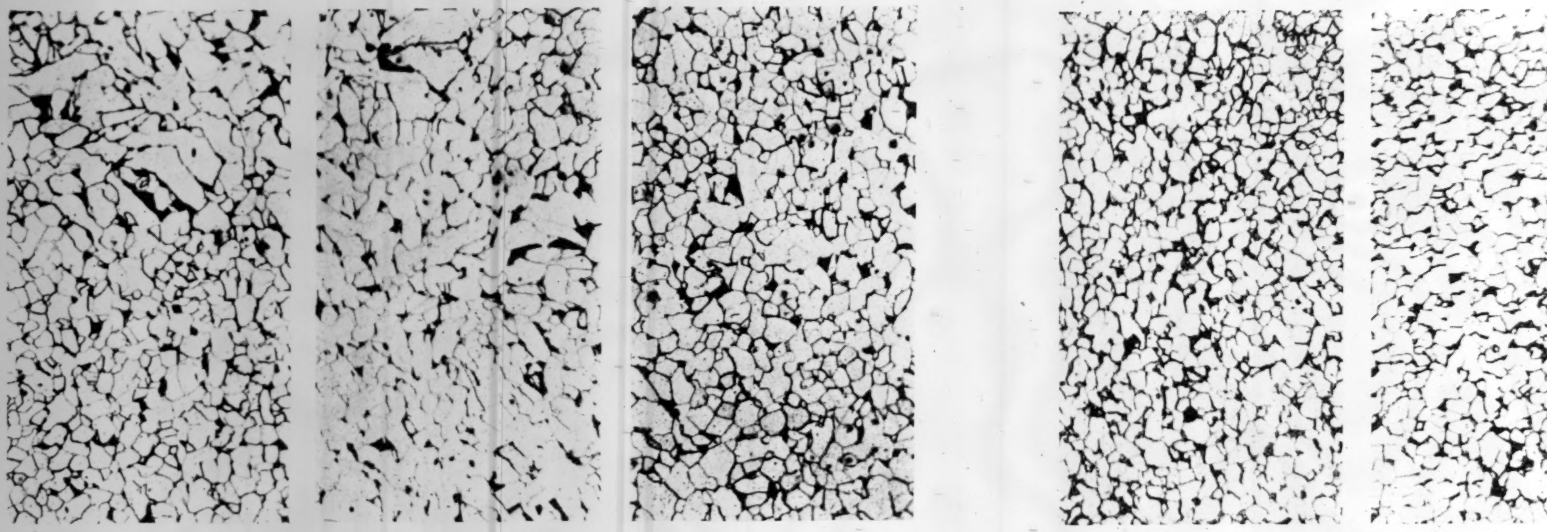


Heat *C:* S = 0.044



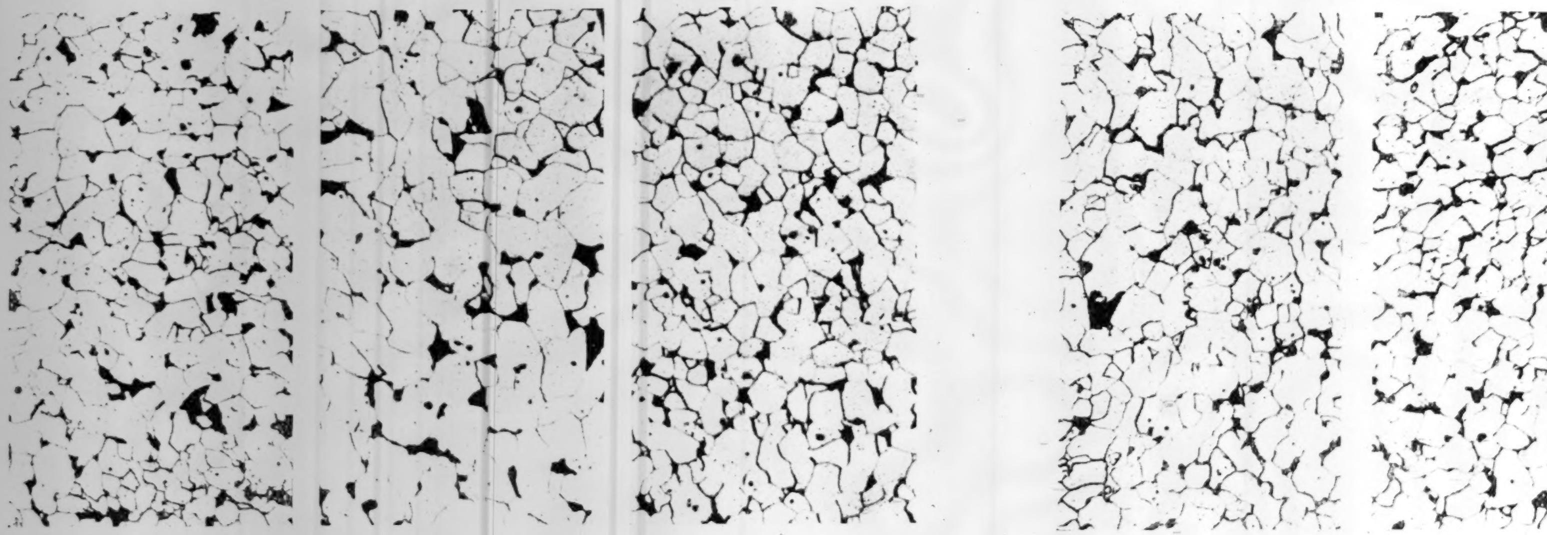
Heat *J:* S = 0.049

Plate XXII.—Photomicrographs of Fourteen Heats of Rivet Steel. Specimens Heated above the Critical Range



Heat *B:* S = 0.037 Heat *C:* S = 0.044 Heat *J:* S = 0.049 Heat *K:* S = 0.058 Heat *D:* S =

rographs of Fourteen Heats of Rivet Steel. Specimens Heated above the Critical Range and Cooled in Air (× 100).



Heat *B:* S = 0.037 Heat *C:* S = 0.044 Heat *J:* S = 0.049 Heat *K:* S = 0.058 Heat *D:* S =

graphs of Fourteen Heats of Rivet Steel. Specimens Heated above the Critical Range and Cooled in Furnace (× 100).

PLATES XXI, XX
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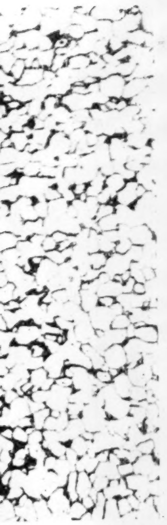
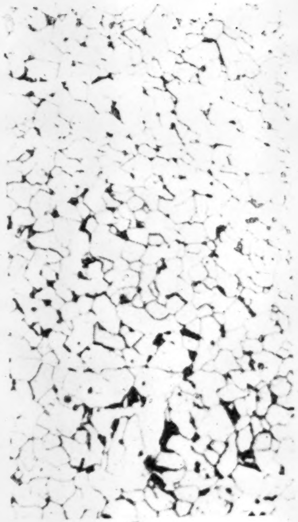
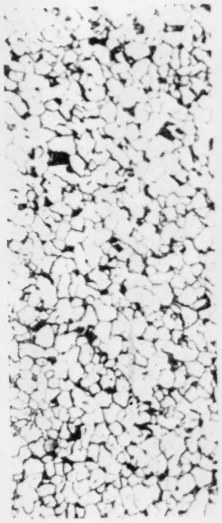


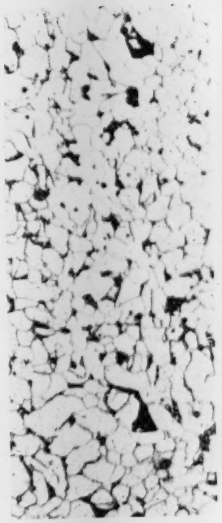
S = 0.060



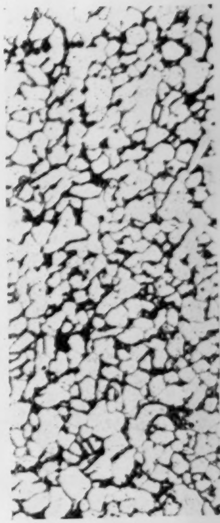
Heat *E:* S = 0.060



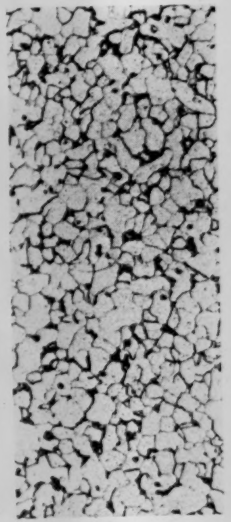
Heat *P:* S = 0.063



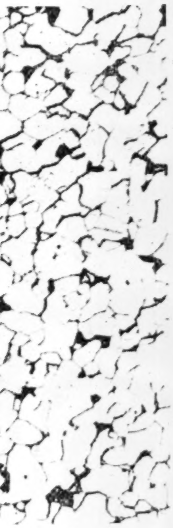
Heat *S:* S = 0.069



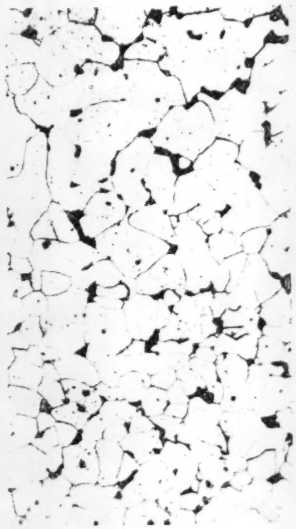
Heat *R:* S = 0.083



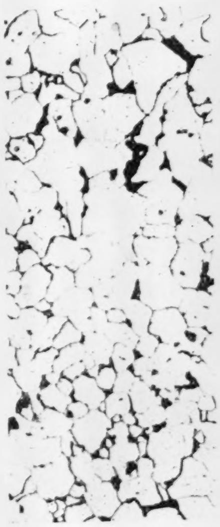
Heat *M:* S = 0.179



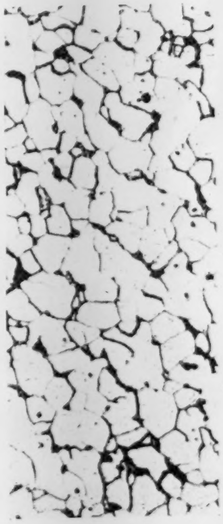
: S = 0.060



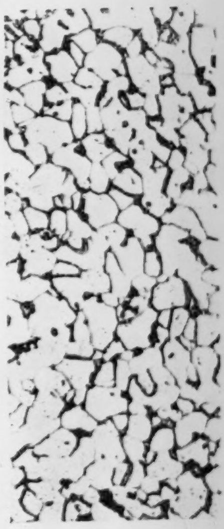
Heat *E:* S = 0.060



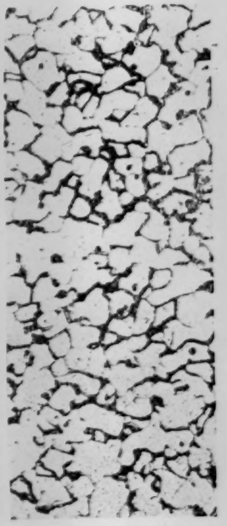
Heat *P:* S = 0.063



Heat *S:* S = 0.069



Heat *R:* S = 0.083



Heat *M:* S = 0.179

work structure is found in the three specimens of lowest sulfur percentage and in the specimen having 0.044 per cent sulfur. In all other specimens of this set the granular structure predominates. It is worthy of note that heat *C*, from which the specimen having 0.044 per cent sulfur and showing a network structure was taken, is graded in Table IV by three observers as first and by one observer as second in the list as regards quantity of non-metallic inclusions.

As shown in Plates XIX and XX the proportion of sorbite or sorbitic pearlite decreases and the proportion of free ferrite increases with increase in percentage of sulfur. A similar variation in proportion of free ferrite is even more conspicuous in the sets of specimens that were cooled in air blast. In the air-cooled specimens shown in Plate XXI, the proportion of pearlite decreases and the proportion of free ferrite increases with increase in percentage of sulfur. A similar variation, though in less degree, is apparent in the furnace-cooled specimens shown in Plate XXII.

In the air-cooled and furnace-cooled specimens there is also a variation in the distribution of pearlite. In the specimens having a low percentage of sulfur, the pearlite exists in relatively large patches, whereas in the specimens having a high percentage of sulfur the pearlite is more evenly distributed on the boundaries of the ferrite grains. In the air-cooled specimens having low sulfur content it is possible to distinguish here and there an aggregate of ferrite and pearlite that evidently originated from a single austenite grain. Such aggregates are not visible in the air-cooled specimens having high percentages of sulfur or in the furnace-cooled specimens. As shown in Plates XXI and XXII, the ferrite grain size tends to decrease with increase in the percentage of sulfur.

The metallographic examination of these fourteen heats of rivet steel would, therefore, seem to indicate that increase in the percentage of residual sulfur tends to increase the proportion of free ferrite and decrease the proportion of sorbite or pearlite. In rapidly cooled specimens, increase in the percentage of residual sulfur apparently is accompanied by a change in the ferrite from the network to the granular arrangement. In more slowly cooled specimens, increase in the percentage of residual sulfur is accompanied by a decrease in the ferrite grain size.

Such variations in microstructure accompanying an increase in the percentage of residual sulfur immediately suggest the possibility that they are due, not to the sulfur in the form of non-metallic inclusions of manganese sulfide, but to an element that exists in solid solution in the ferrite. In order to discuss this theory intelligently, however, it is necessary to obtain further information in regard to the nature of the differences in microstructure between the material of low and high sulfur content. It is necessary to inquire into the nature of the difference between the micro-constituent containing the cementite as it exists in low-sulfur and high-sulfur steels. Such questions can be answered only by an investigation of the microstructure at much higher magnifications.

Investigation of Microstructure at Magnifications of 1000 and 4000.—Investigation of this material at high magnifications has thrown much light on the real nature of the variations in microstructure with increase in sulfur content. Information has also been obtained in regard to the nature of the changes that take place in cooling through the critical range. The evidence thus obtained is presented in a number of photomicrographs at magnifications of 1000 and 4000.

Specimens from each of the fourteen heats of rivet steel were examined microscopically under oil immersion with a 2-mm. apochromatic objective and × 14 and × 18 compensating eye pieces. The source of illumination was a "Pointolite" lamp in which an electrically heated tungsten ball furnishes the light. To illustrate the microstructures thus observed, two specimens of low-sulfur and two of high-sulfur steel were selected and from these specimens photomicrographs were made.

A Wratten K-1 light filter was used in the first photomicrographs made at high magnification. In the later photomicrographs this yellow filter was replaced by a C-4 filter; the violet light transmitted by this filter, being of shorter wave length, gives better resolution of detail at high magnification than does the yellow light transmitted by the K-1 filter.

After considerable experimentation it was found that a 1-percent alcoholic solution of nitric acid gave the best etching results. The slow action of this solution makes it possible to obtain the exact depth of etching desired. To show the structure of the pearlite or sorbite to best advantage it is necessary to stop the etching before the ferrite grain boundaries become distinct. In some of the photomicrographs, therefore, the ferrite grain boundaries are invisible or indistinct. To show the relationship of the ferrite grain boundaries to the rest of the microstructure, however, it was necessary to make additional photomicrographs in which these grain boundaries have been made distinct.

Description of Microstructure as Seen at High Magnification.—Microstructures found in two specimens of low-sulfur and two specimens of high-sulfur steel selected for illustration are shown at magnification of 1000 in Plates XXIII to XXVI, inclusive. Microstructures found in the same specimens are shown at magnification of 4000 in Plates XXVII to XLV, inclusive. Many of the photomicrographs at magnification of 4000 show portions of the same regions that are shown in the photomicrographs at magnification of 1000. The photomicrographs in these two sets have been arranged as far as is practicable according to heat treatment and composition. This is not the order in which they will be discussed.

In making these two sets of photomicrographs the same objective was used. Under such conditions, according to views frequently expressed, it might be expected that no more detail would be visible at magnification of 4000 than at magnification of 1000. The results, however, would seem to indicate that better detail is obtained by enlarging the image to 4000 diameters before photographing it than would be obtained if a photomicrograph at 1000 magnification were magnified four diameters by a lens. Moreover, details that would be overlooked at magnification of 1000 are conspicuous at magnification of 4000.

A photomicrograph at magnification of 4000, therefore, has distinct advantages over one at magnification of 1000. It has the decided disadvantage, however, that it includes such a small portion of the material examined that its relationship to surrounding regions is sometimes not clear. For this reason it was thought advisable to present photomicrographs at magnification of 1000 as well as 4000. Photomicrographs at both magnifications give a clearer conception of the microstructure than that obtainable by use of either magnification alone.

Comparison of the photomicrographs of low and high-sulfur steels at the higher magnifications confirms, as was to be expected, the conclusions reached by examination of these specimens at magnification of 100. For example, the proportion of free ferrite is seen to be greater in the high than in the low-sulfur steels.

Examination at high magnification was not for the purpose of investigating the microstructure of free ferrite but for investigating the microstructure of the constituent that at magnification of 100 appears merely as dark areas. This dark-etching constituent is known to be a complex of ferrite and cementite, the cementite being of various degrees of fineness and of dispersion in the ferrite. The principal purpose of the examination at high magnification was to determine whether the difference in proportion of this carbide complex to free ferrite in low and high-sulfur steels is due to difference in size of cementite particles, to difference in degree of dispersion of cementite particles, or to both.

In order to make comparison of fineness of cementite particles, lightly etched specimens should be compared. In specimens so deeply etched as to develop the ferrite grain boundaries distinctly, the structure of the carbide complex is made less distinct and is sometimes obscured so that no correct estimate can be made of the fineness of cementite particles.

Comparison of suitable photomicrographs at magnification of 4000 makes it evident that, although the fineness of cementite particles varies with the heat treatment, there is little if any difference in fineness between the cementite particles of low and high-sulfur steels that have received the same heat treatment. Comparison of water-quenched low and high-sulfur steels, as illustrated in Plates XXIX, XXX, XXXIII and XXXIV, shows that the differences in microstructure previously noticed at magnification of 100 are not due to differences in fineness of cementite particles. Comparison of oil-quenched low and high-sulfur steels, as illustrated in Plates XXXV, XXXVI, XXXVIII, and XXXIX, shows that the difference in fineness of cementite particles is slight. Comparison of specimens cooled in air blast, as illustrated in Plates XL, XLI and XLIII, seems to show that the difference in microstructure between low and high-sulfur steels is chiefly due not to difference in fineness but to difference in distribution of cementite particles. Similar conclusions were reached from examination of air-cooled specimens (not illustrated in this report) at magnification of 4000. A comparison of furnace-cooled specimens, illustrated in Plates XLIV and XLV, shows that the laminations in the pearlite in low and high-sulfur steels are similar. The irregular arrangement of the pearlite in Fig. 56 of Plate XLIV is due to the fact that the cementite plates make only a slight angle with the polished surface of the metal.

Comparison at magnification of 4000 of the lightly etched water-quenched specimens with similar specimens that have been cooled in oil, air blast, and furnace, respectively, seems to show that the coarseness of the cementite particle increases with decrease in the rate of cooling. In the water-quenched specimens the cementite particles when magnified 4000 diameters appear of the fineness of dust. In the oil-quenched specimens they appear slightly larger. In the specimens that were cooled in air blast, the cementite particles appear as granules. In the air and furnace-cooled specimens they appear as plates.

Since the difference in microstructure between low and high-sulfur steels that have received the same heat treatment is evidently not due to difference in the fineness of the cementite particles, it must be due to differences in the distribution of those particles. In the interiors of areas of carbide complex in water-quenched low and high-sulfur steels, as illustrated in Plates XXIX, XXX, XXXIII and XXXIV, the cementite particles have practically the same degree of dispersion. Little if any difference can be observed between the appearance of the interior of the large central area of carbide complex visible in Plate XXXIV and the interiors of the scattered carbide areas visible in Plates XXIX and XXX. Comparison of oil-quenched specimens, as illustrated in Plates XXXV, XXXVI, XXXVIII and XXXIX, would seem to indicate that after cooling at this rate the degree of dispersion of cementite particles in the interior of an area of carbide complex is slightly less in high-sulfur than in low-sulfur steels. Comparison of specimens cooled in air blast, as illustrated in Plates XL, XLI and XLIII, shows that after cooling at this rate the cementite particles are much more evenly distributed throughout an area of carbide complex in low-sulfur than in high-sulfur steels. Comparison of all these photomicrographs, therefore, has shown that there is a greater tendency toward agglomeration of the cementite particles in high than in low-sulfur steels.

It is chiefly on the boundaries of the areas of carbide complex that the cementite particles tend to agglomerate. In water-quenched and oil-quenched specimens agglomeration is found on these boundaries alone. In more slowly cooled specimens some agglomeration has occurred within the areas of carbide complex. Dark boundaries are visible in the photomicrographs of lightly etched specimens, Plates XXIII-XXVI, Figs. 37, 38, 39, 41, 42, 43, 45, 46, 47, 49 and 50, at magnification of 1000. The boundaries are heavier in the high-sulfur steels (in which the proportion of free ferrite is large) than in the low-sulfur steels. As shown at higher magnification these dark boundaries consist of closely packed cementite particles.

A striking characteristic of the dark boundary strip around an area of carbide complex, is the definiteness of the line of demarcation between this strip and the adjacent free ferrite. On the other side of the strip, the line of demarcation between it and the remainder of the area of carbide complex is often nearly as distinct, though more irregular. This is especially noticeable in the water-quenched and oil-quenched specimens. Many of these areas of carbide complex as shown at magnification of 1000 and 4000 resemble dust particles or particles of fine sand that have been widely scattered and

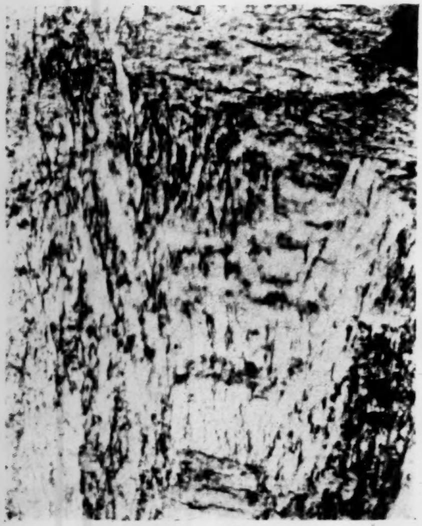


FIG. 35.—Heat *A*: S = 0.028.
(Micrograph × 4000 not shown.)

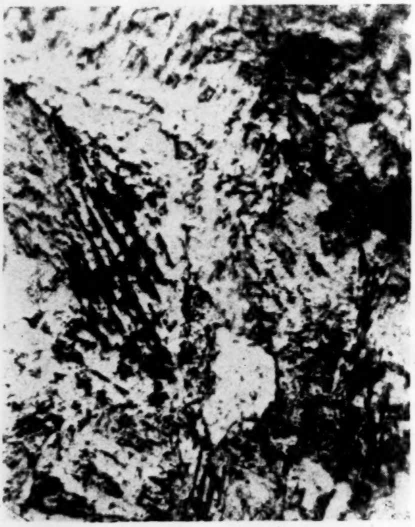


FIG. 36.—Heat *A*: S = 0.028.
(Micrograph × 4000 not shown.)

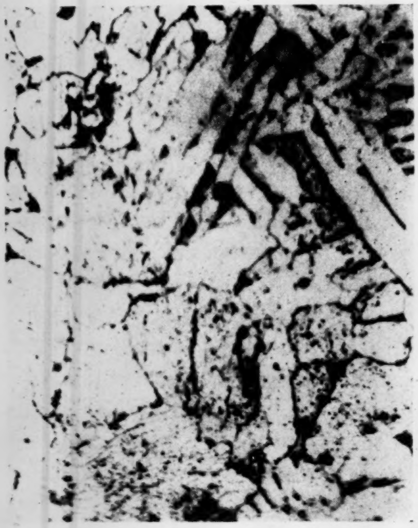


FIG. 37.—Heat *R*: S = 0.083.
(For Micrograph × 4000
see Pl. XXVII.)

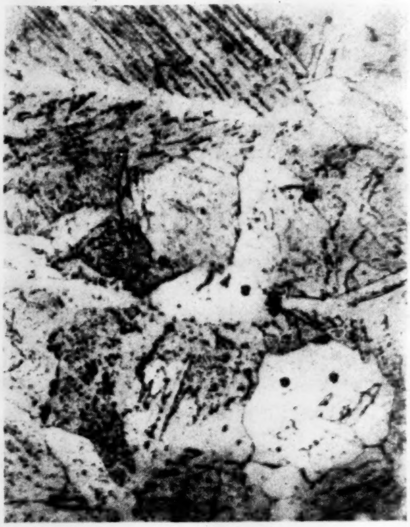


FIG. 38.—Heat *M*: S = 0.179.
(For Micrograph × 4000
see Pl. XXVIII.)

PLATE XXIII.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN ICED BRINE (× 1000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 14.
Filter: K-1.
Exposure: 25 seconds.

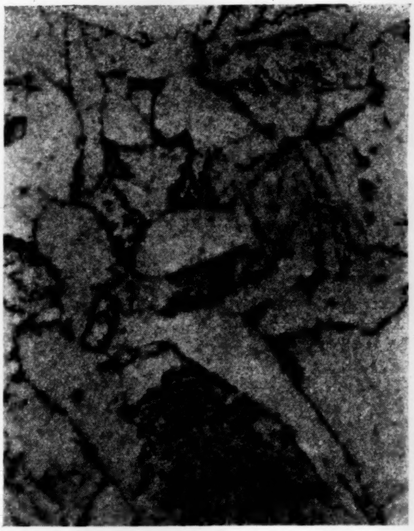


FIG. 39.—Heat *A*: S = 0.028. (For Micrograph × 4000 see Pl. XXXI.)

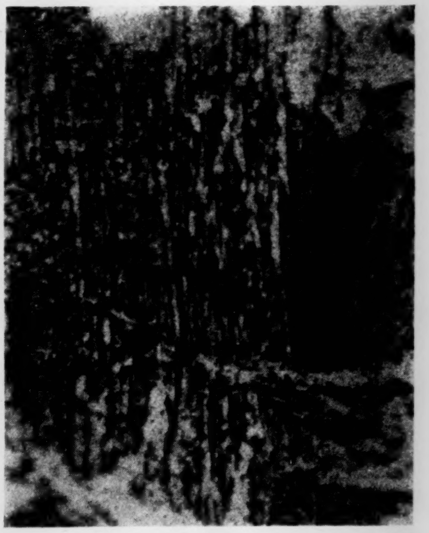


FIG. 40.—Heat *A*: S = 0.028. (For Micrograph × 4000 see Pl. XXXII.)

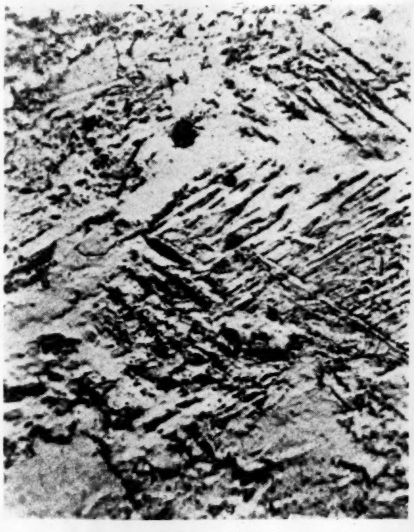


FIG. 41.—Heat *R*: S = 0.083. (For Micrograph × 4000 see Pl. XXXIII.)

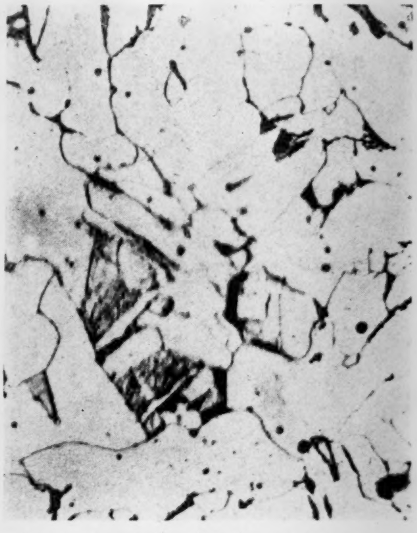


FIG. 42.—Heat *M*: S = 0.179. (For Micrograph × 4000 see Pl. XXXIV.)

PLATE XXIV.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 1000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 14.
Filter: K-1.
Exposure: 25 seconds.

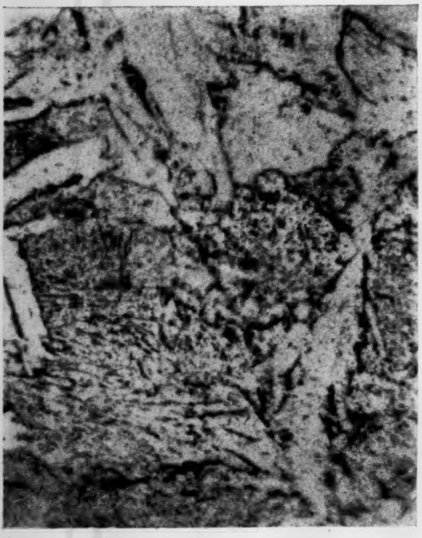


FIG. 43.—Heat *A:* S = 0.028.
(For Micrograph × 4000
see Pl. XXXVI.)

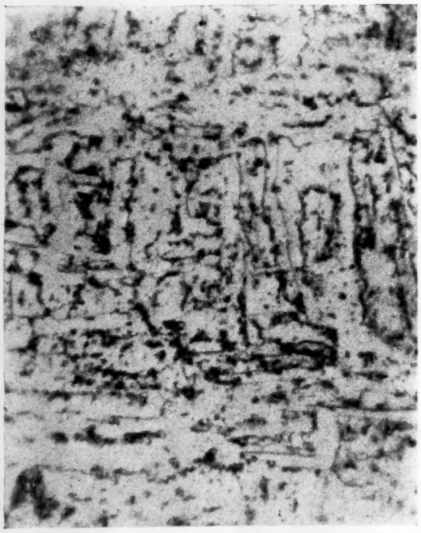


FIG. 44.—Heat *F:* S = 0.031.
(For Micrograph × 4000
see Pl. XXXVII.)

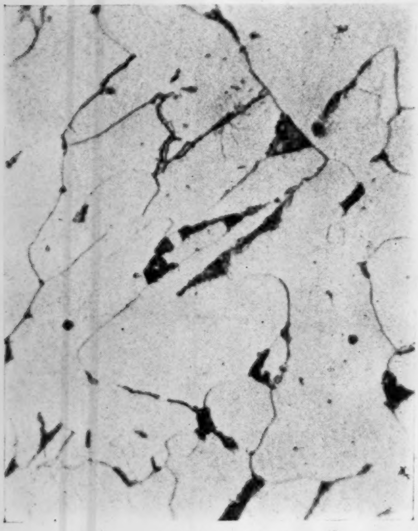


FIG. 45.—Heat *R:* S = 0.083.
(For Micrograph × 4000
see Pl. XXXVIII.)

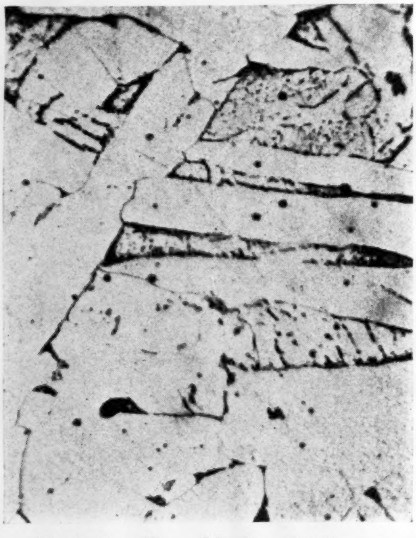


FIG. 46.—Heat *M:* S = 0.179.
(For Micrograph × 4000
see Pl. XXXIX.)

PLATE XXV.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 1000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 14.
Filter: K-1.
Exposure: 25 seconds.

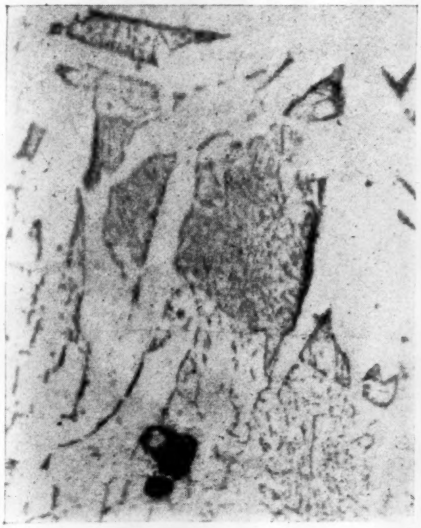


FIG. 47.—Heat *A:* S = 0.028.
(For Micrograph × 4000
see Pl. XL.)

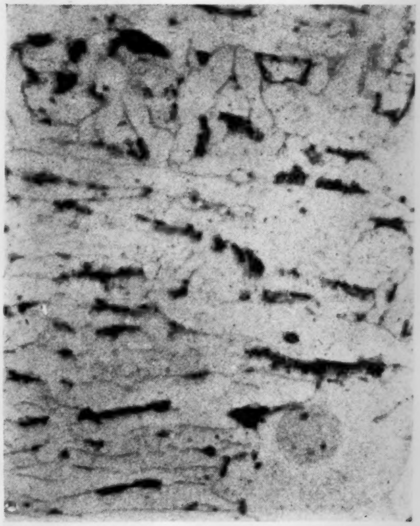


FIG. 48.—Heat *F:* S = 0.031.
(For Micrograph × 4000
see Pl. XLII.)

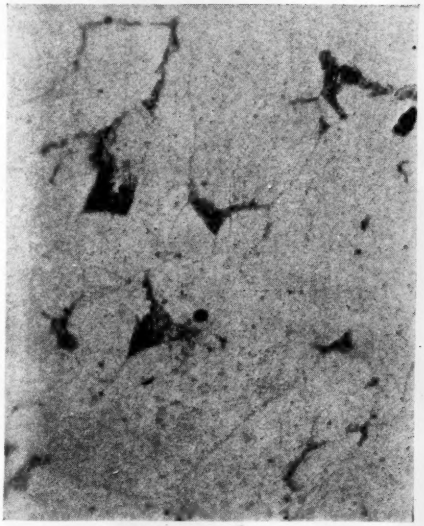


FIG. 49.—Heat *R:* S = 0.083.
(For Micrograph × 4000
see Pl. XLIII, Fig. 53.)

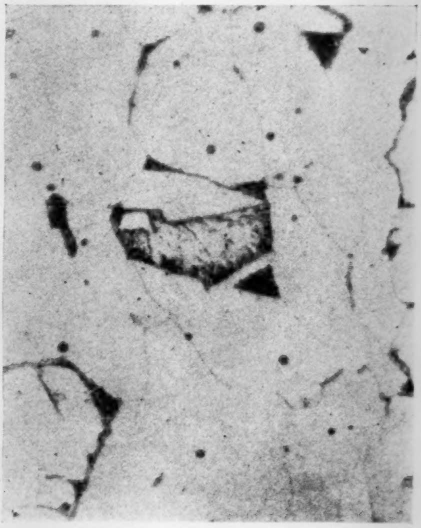


FIG. 50.—Heat *M:* S = 0.179.
(For Micrograph × 4000
see Pl. XLIII, Fig. 54.)

PLATE XXVI.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND COOLED IN AIR BLAST (× 1000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 14.
Filter: K-1.
Exposure: 25 seconds.

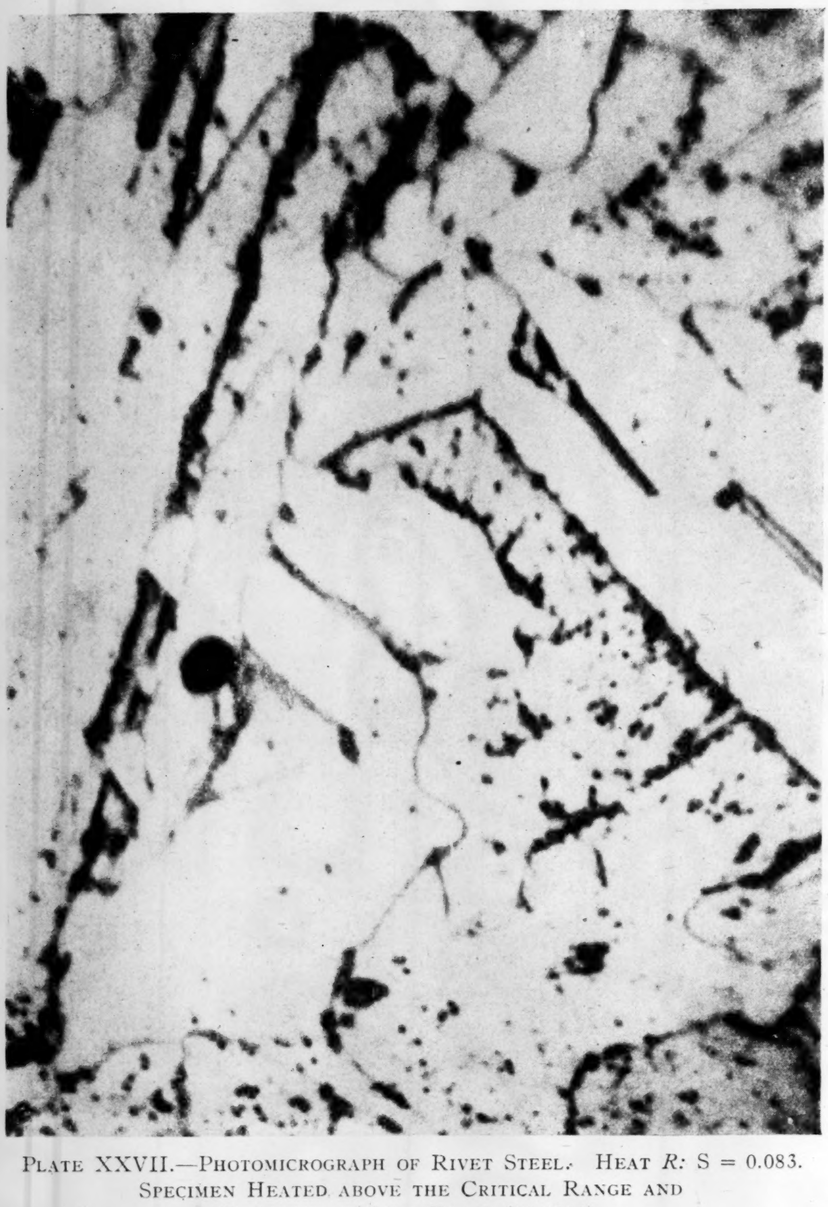


PLATE XXVII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *R:* S = 0.083.
SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND
QUENCHED IN ICED BRINE (× 4000).
(For Micrograph × 1000 see Pl. XXIII, Fig. 37.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

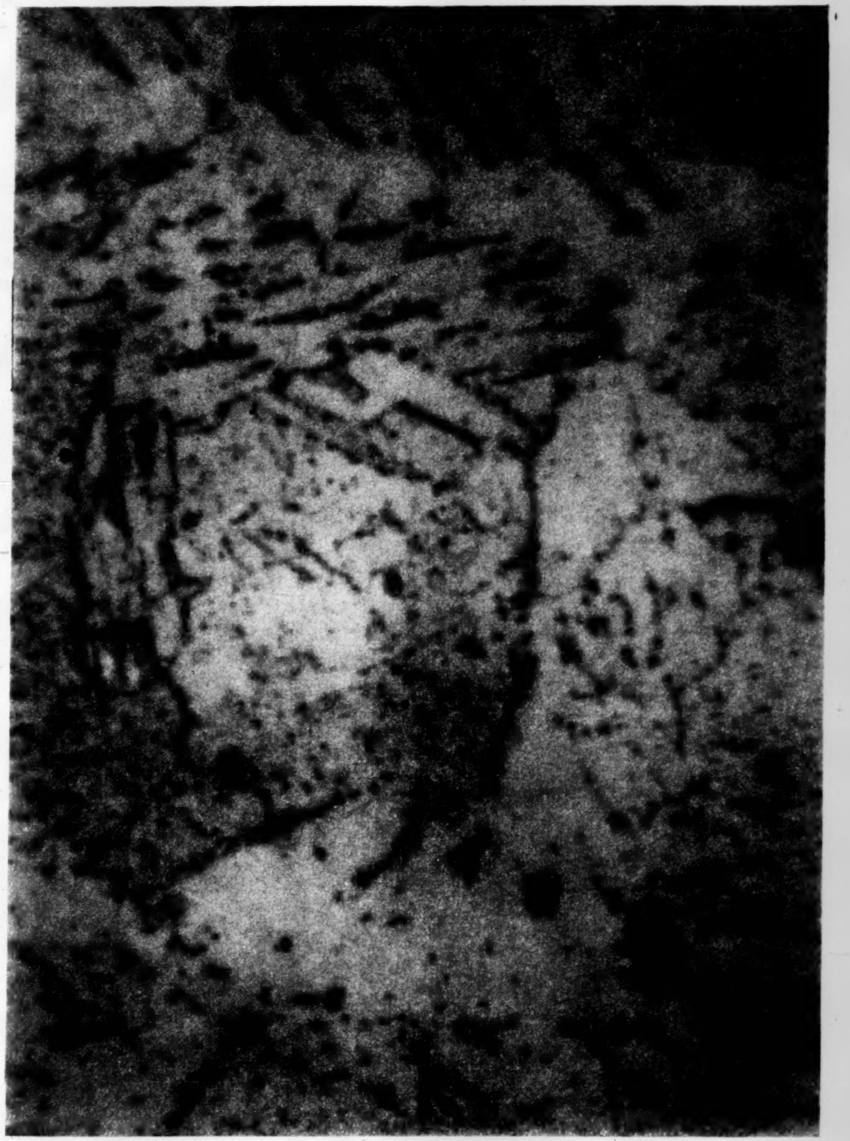


PLATE XXVIII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *M:* S = 0.179. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN ICED BRINE (× 4000).
(For Micrograph × 1000 see Pl. XXIII, Fig. 38.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: C-4.
Exposure: 4 minutes, 13 seconds.

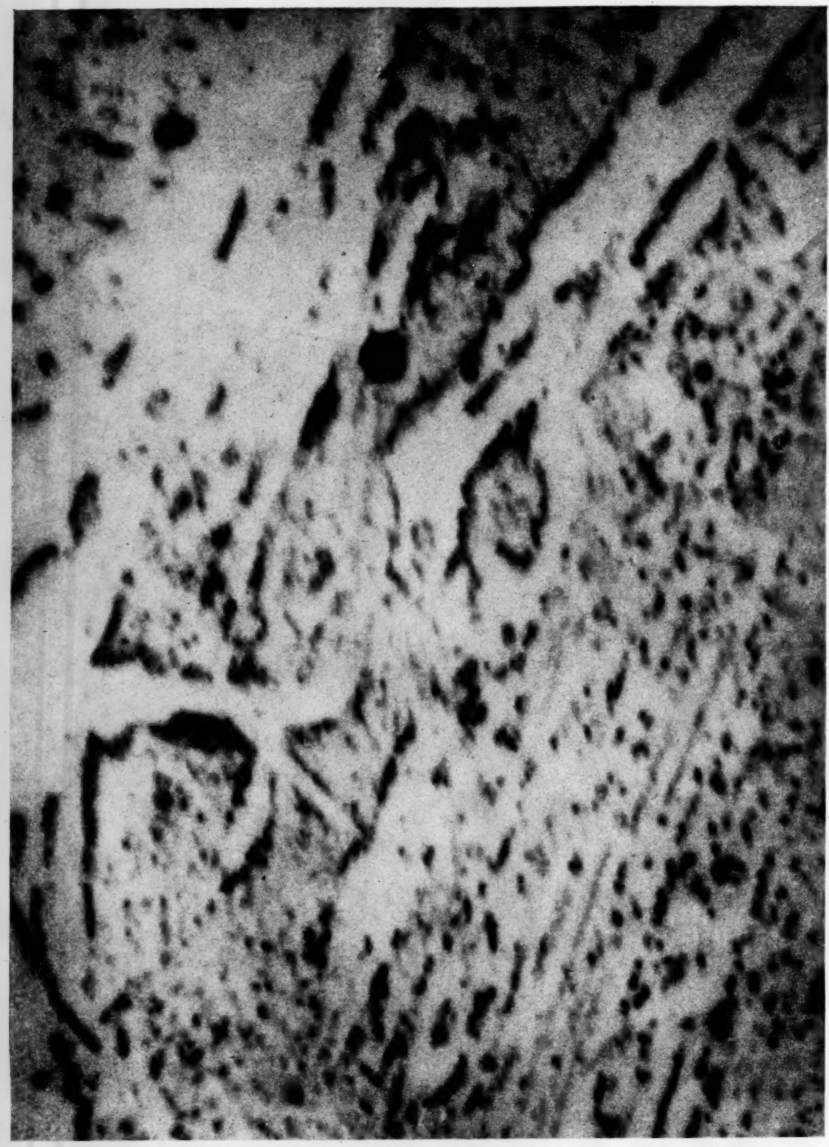


PLATE XXIX.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A:* S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 4000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

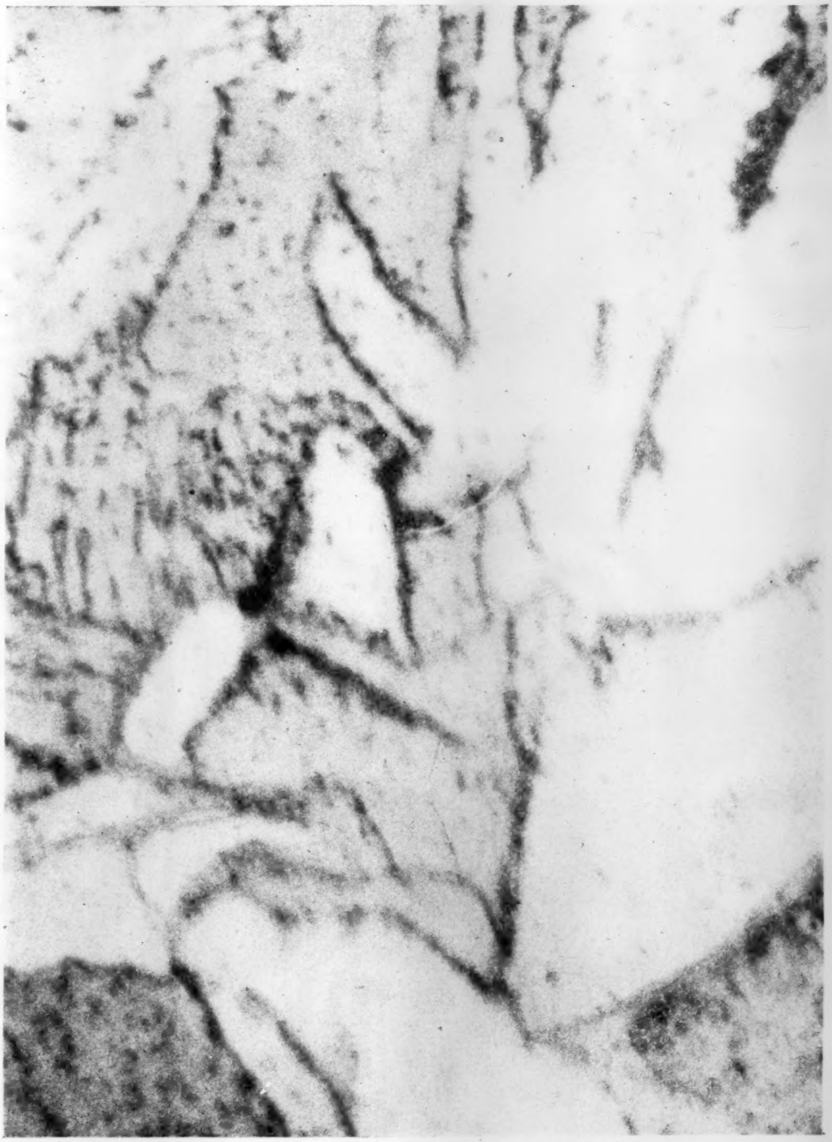


PLATE XXX.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 4000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

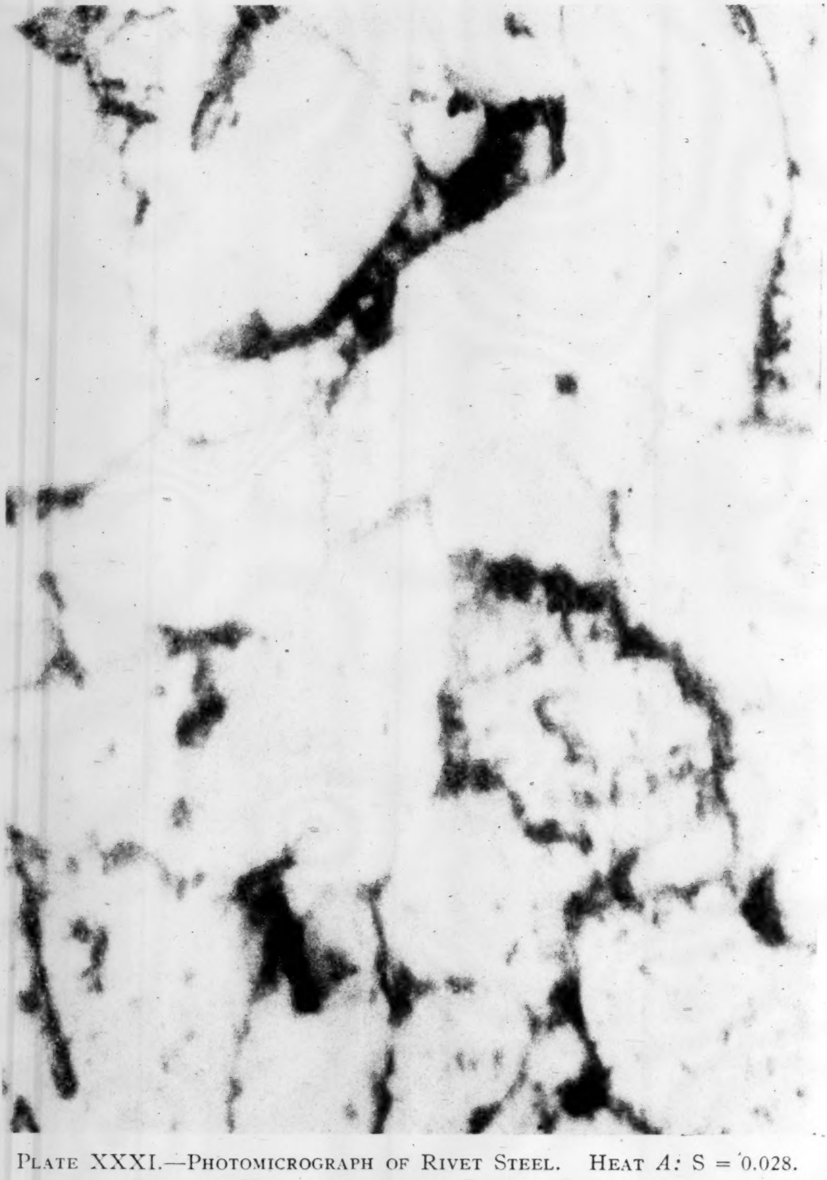


PLATE XXXI.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A:* S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 4000).

(For Micrograph × 1000 see Pl. XXIV, Fig. 39.)

Etch: 5-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

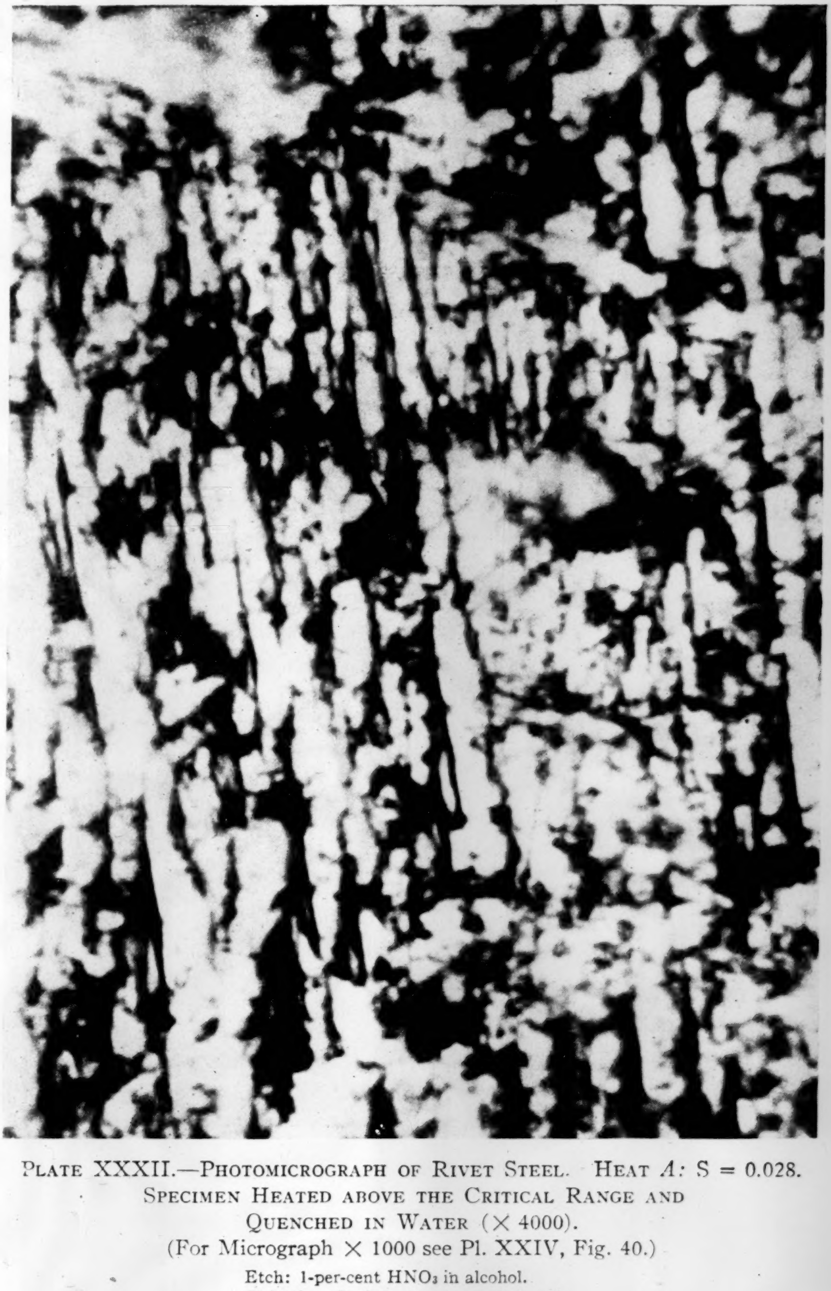


PLATE XXXII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028.
SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND
QUENCHED IN WATER (× 4000).
(For Micrograph × 1000 see Pl. XXIV, Fig. 40.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

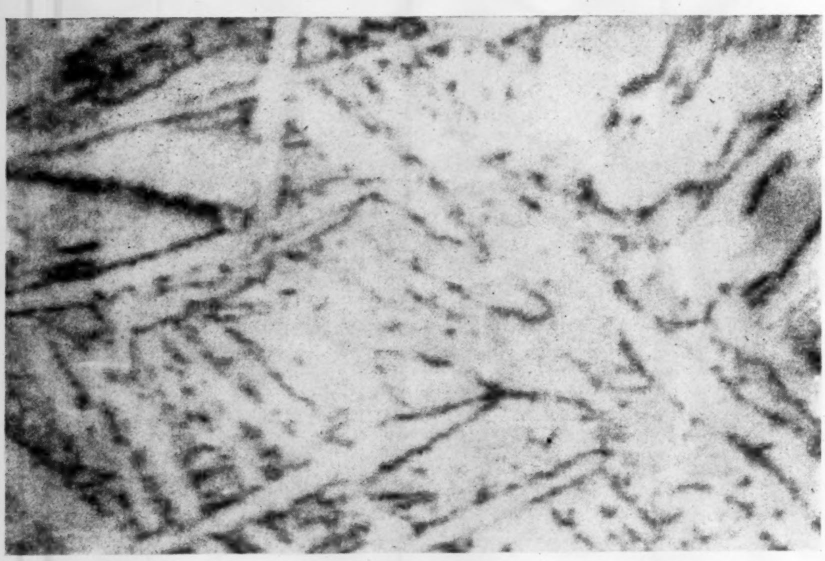


FIG. 51.

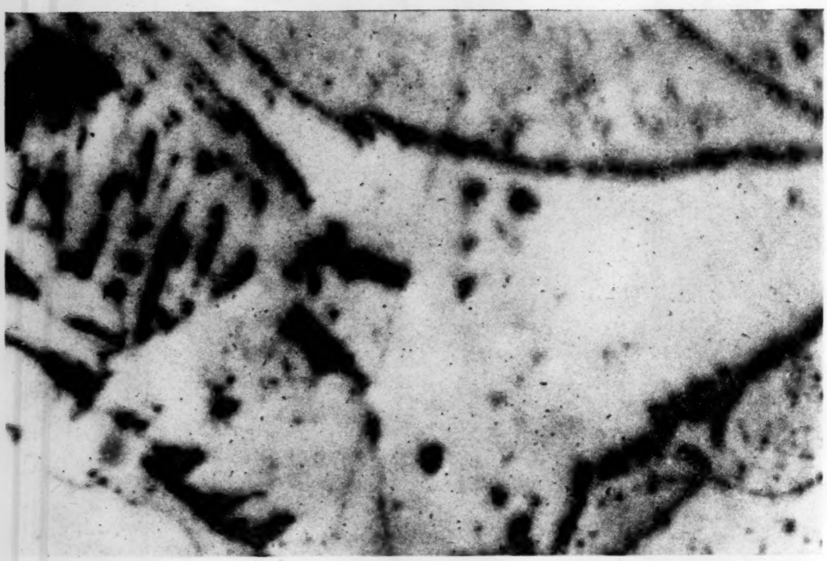


FIG. 52.

PLATE XXXIII.—PHOTOMICROGRAPHS OF RIVET STEEL. HEAT *R:* S = 0.083.
SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND
QUENCHED IN WATER (× 4000).
(For Micrograph × 1000 see Pl. XXIV, Fig. 41.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

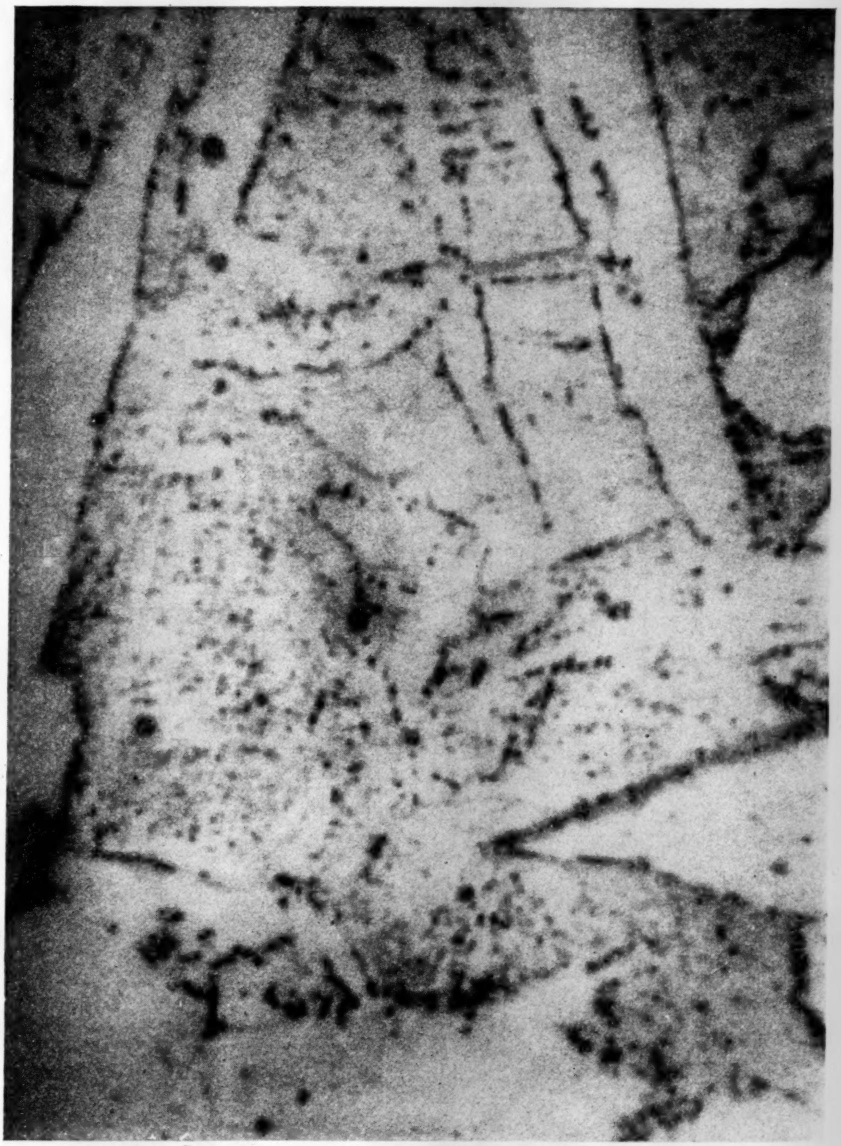


PLATE XXXIV.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *M*: S = 0.179. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN WATER (× 4000).

(For Micrograph × 1000 see Pl. XXIV, Fig. 42.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

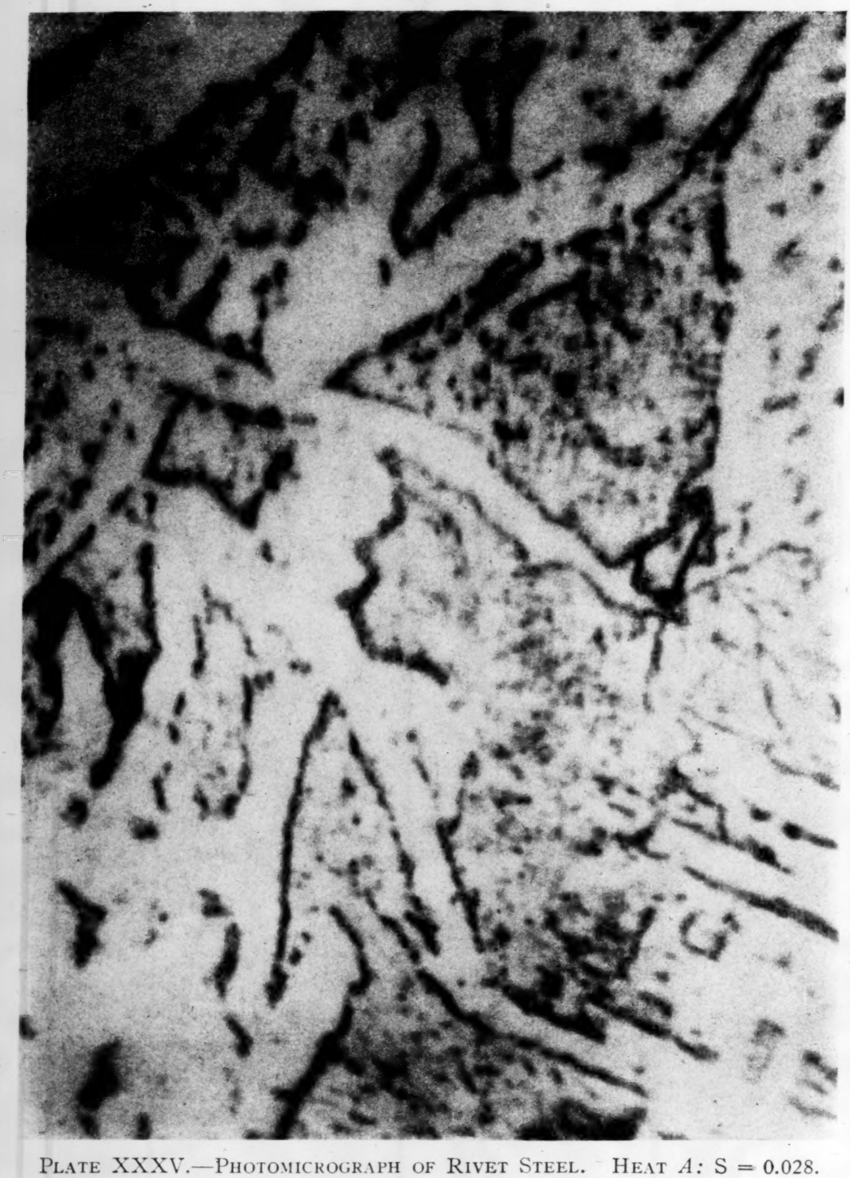


PLATE XXXV.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 4000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

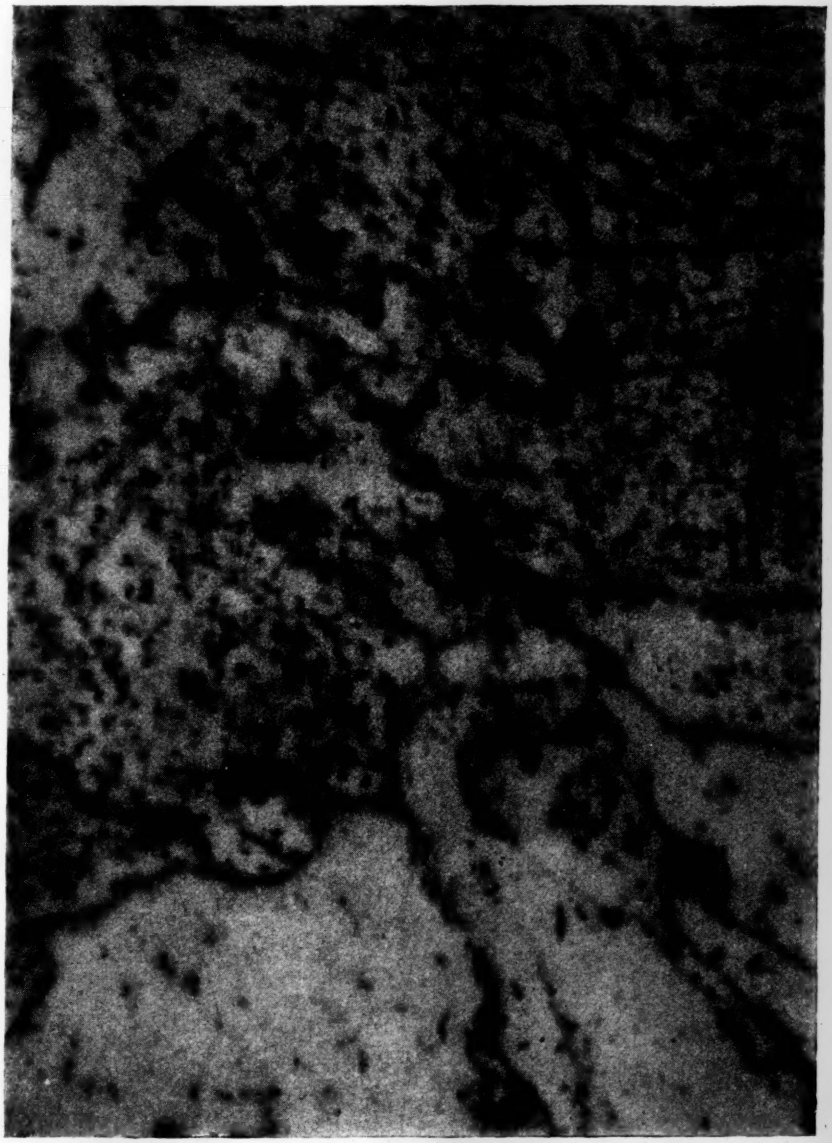


PLATE XXXVI.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 4000).

(For Micrograph × 1000 see Pl. XXV, Fig. 43.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

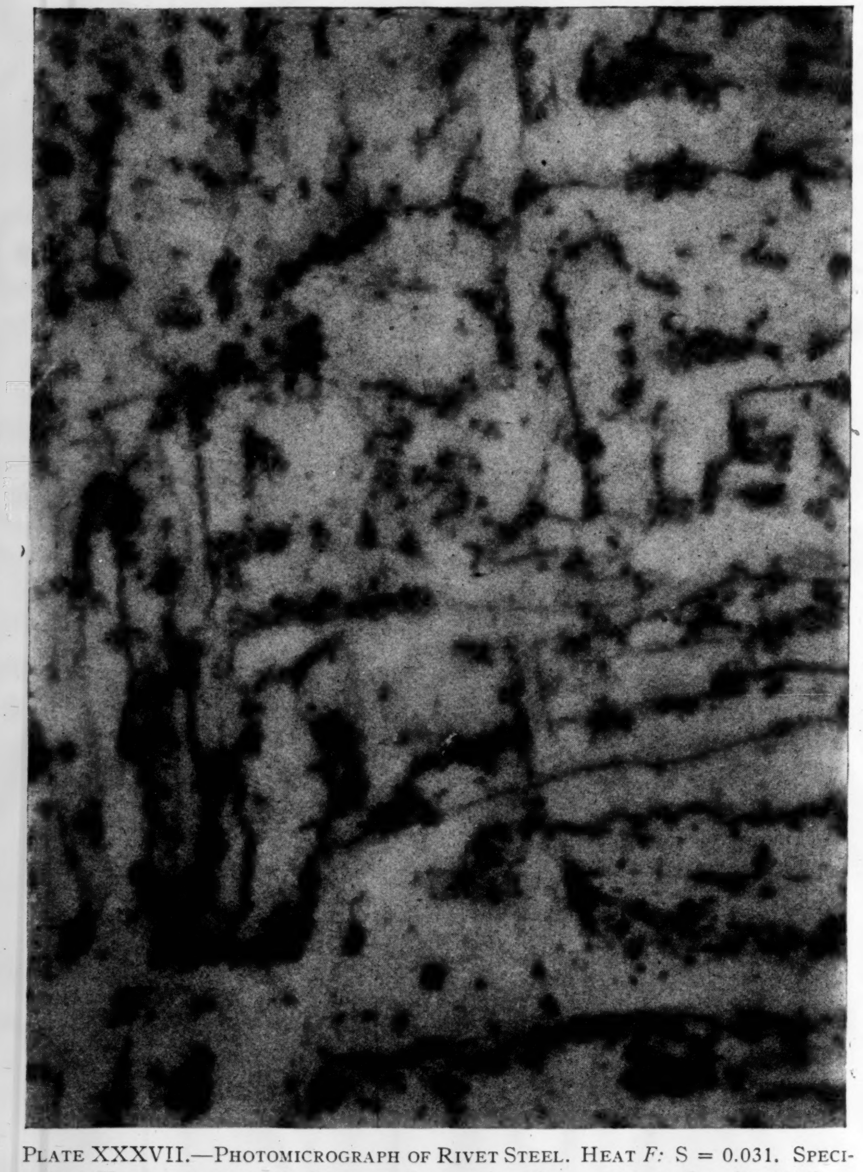


PLATE XXXVII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *F:* S = 0.031. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 4000).

(For Micrograph × 1000 see Pl. XXV, Fig. 44.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: C-4.
Exposure: 4 minutes, 13 seconds.

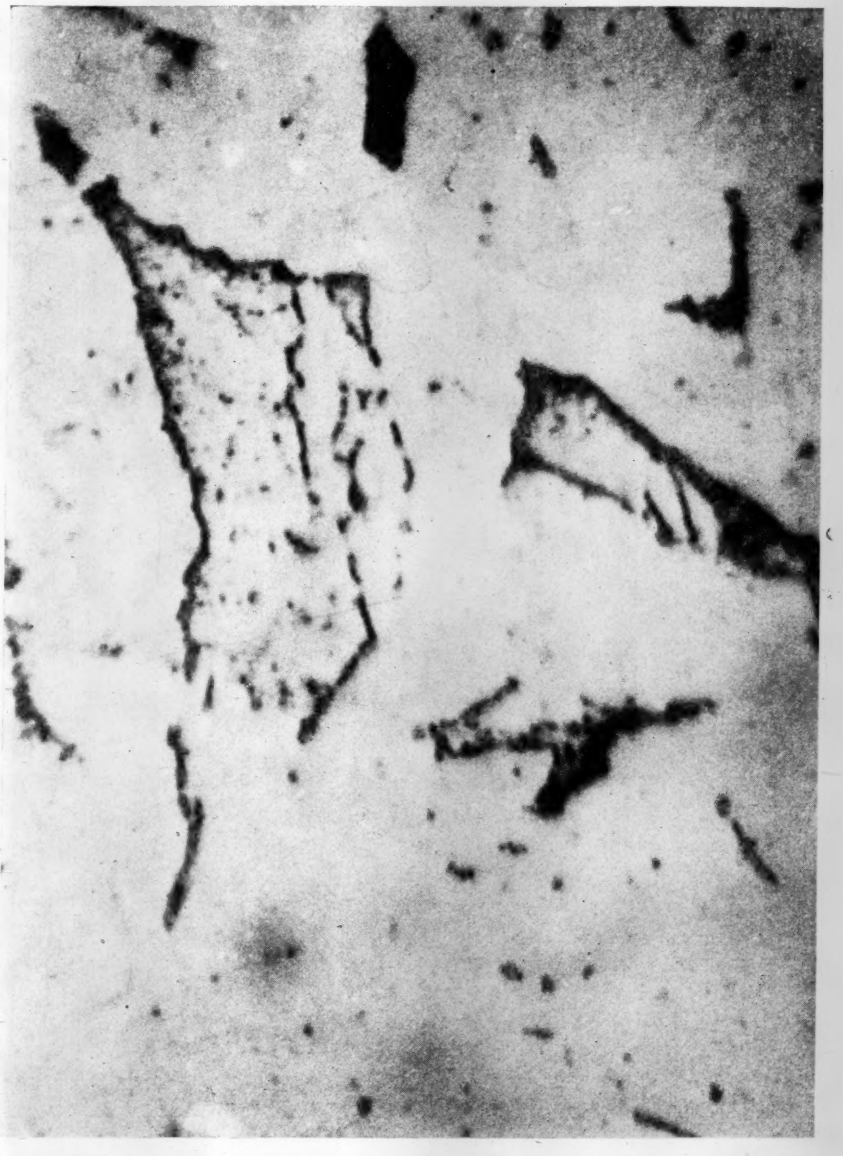


PLATE XXXVIII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *R:* S = 0.083. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 4000).
(For Micrograph × 1000 see Pl. XXV, Fig. 45.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

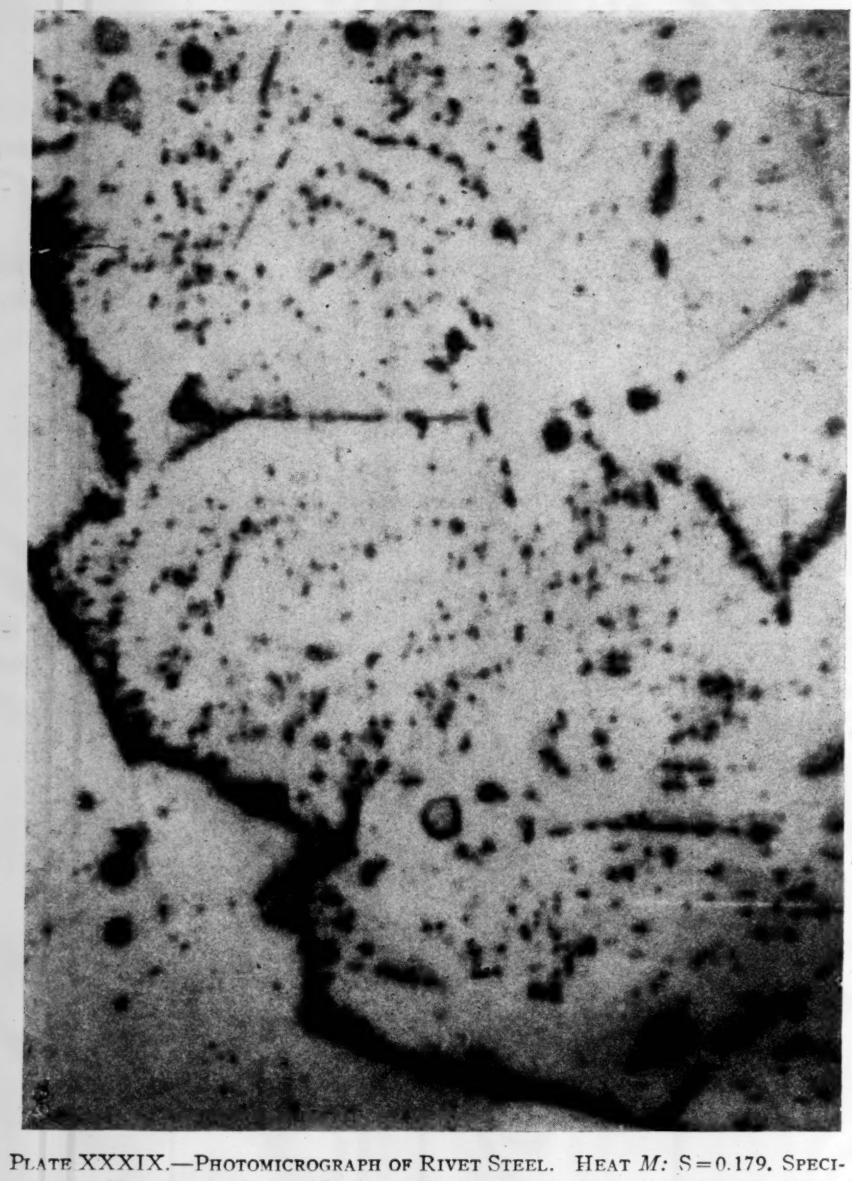


PLATE XXXIX.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *M:* S = 0.179. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND QUENCHED IN OIL (× 4000). (For Micrograph × 1000 see Pl. XXV, Fig. 46.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

then swept into smaller areas. In the water-quenched specimens, shown in Plates XXIX, XXX, XXXIII and XXXIV, in the oil-quenched specimens shown in Plates XXXV, XXXVIII, and XXXIX, and in the specimen cooled in air blast, shown in Plate XL, this resemblance is most conspicuous.

When the sharpness of the lines of demarcation between areas of carbide complex and adjacent ferrite was noticed in the lightly etched specimens, it seemed most probable that these lines were ferrite grain boundaries. Examination of the specimens after deeper etching showed that this conjecture was correct. As shown in Plates XXVII, XXX, XXXI, XXXVI, XXXVII and XLII the boundaries between free ferrite and agglomerated cementite particles are ferrite grain boundaries. After this had been determined, attempt was made by relatively deep etching to detect grain boundaries of the ferrite of the carbide complex. It was difficult to make satisfactory photomicrographs of these deeply etched areas on account of the irregularity in distance of the metal surface from the objective. Examination with changing focus, however, showed that even in regions such as that shown at 1000 magnification in Plate XXIV, Fig. 40, ferrite grain boundaries can be detected. In a photomicrograph at higher magnification of a portion of this region, as shown in Plate XXXII, the ferrite appears as elongated grains, bounded on each side by rows of cementite particles and transversely by numerous boundaries. In somewhat more open regions such as that shown in Plate XLII some ferrite grains have not lost their elongated shape.

The above described areas of agglomerated cementite particles, existing sometimes as boundaries of areas of carbide complex, and sometimes in roughly parallel strips as illustrated in Plate XXVI, Fig. 48, and in Plates XXVIII, XXXIII, XLI and XLII, are due to the fact that the cementite particles have been crowded into these strips by the advancing boundaries of growing ferrite grains. Whether the cementite particles themselves or the solid solution from which they originated were thus crowded into smaller space by advancing grain boundaries will be discussed later.

Variations in ferrite grain growth, therefore, are evidently the dominant influence in causing the variations in microstructure found in quickly cooled specimens of low-carbon steel. Unless the rate of cooling through the transition range is relatively slow, growth of cementite particles is of minor importance in decreasing the proportion of carbide complex to free ferrite. In the furnace-cooled specimens, illustrated in Plates XLIV and XLV, some of the cementite laminae show a tendency to become spheroidized. This

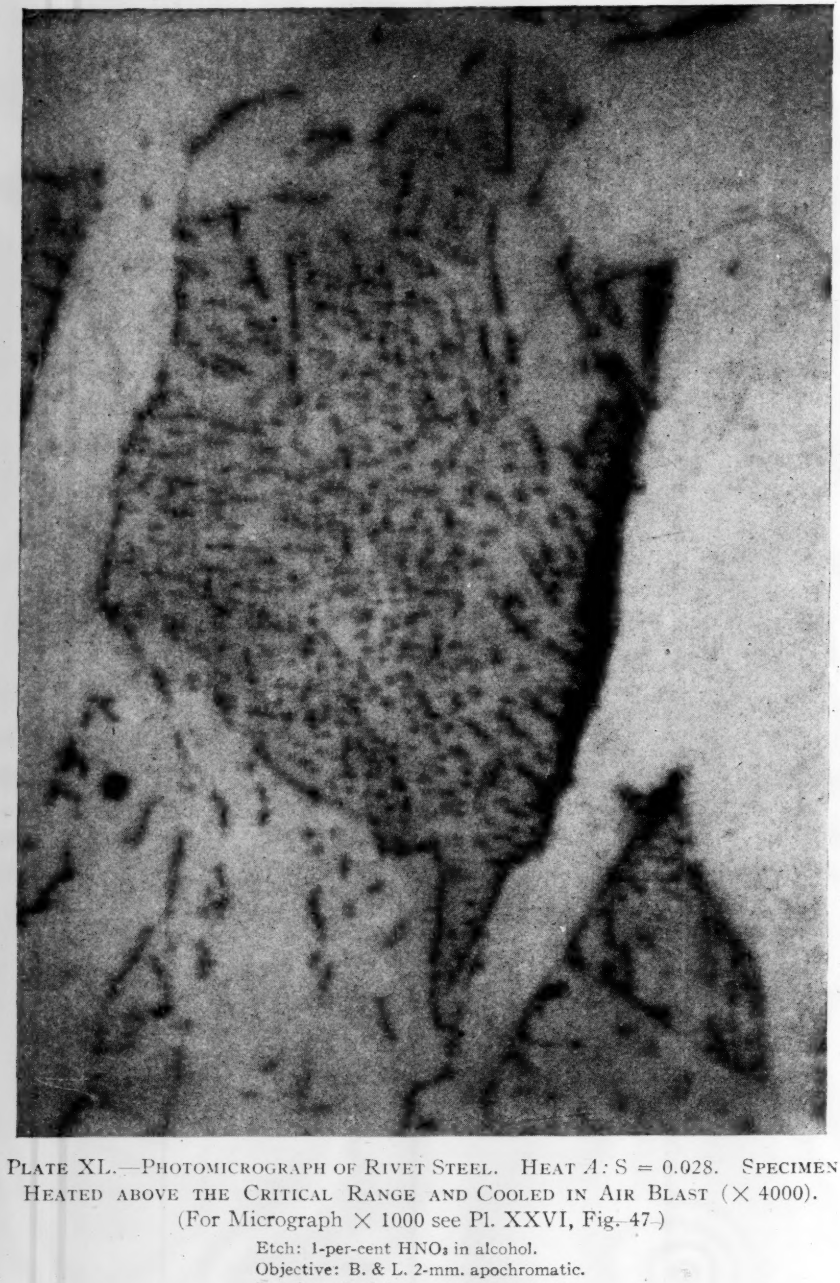


PLATE XL.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND COOLED IN AIR BLAST (× 4000). (For Micrograph × 1000 see Pl. XXVI, Fig. 47.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

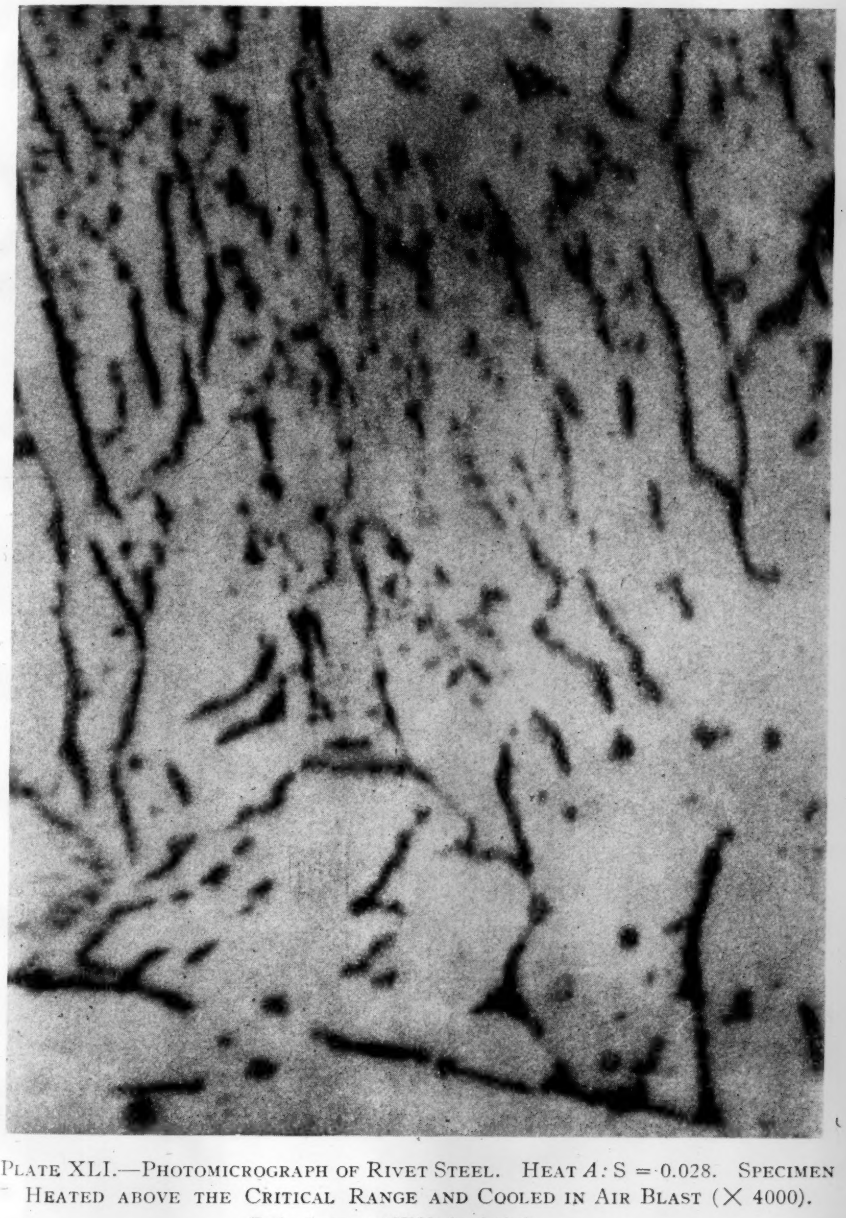


PLATE XLI.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND COOLED IN AIR BLAST (× 4000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

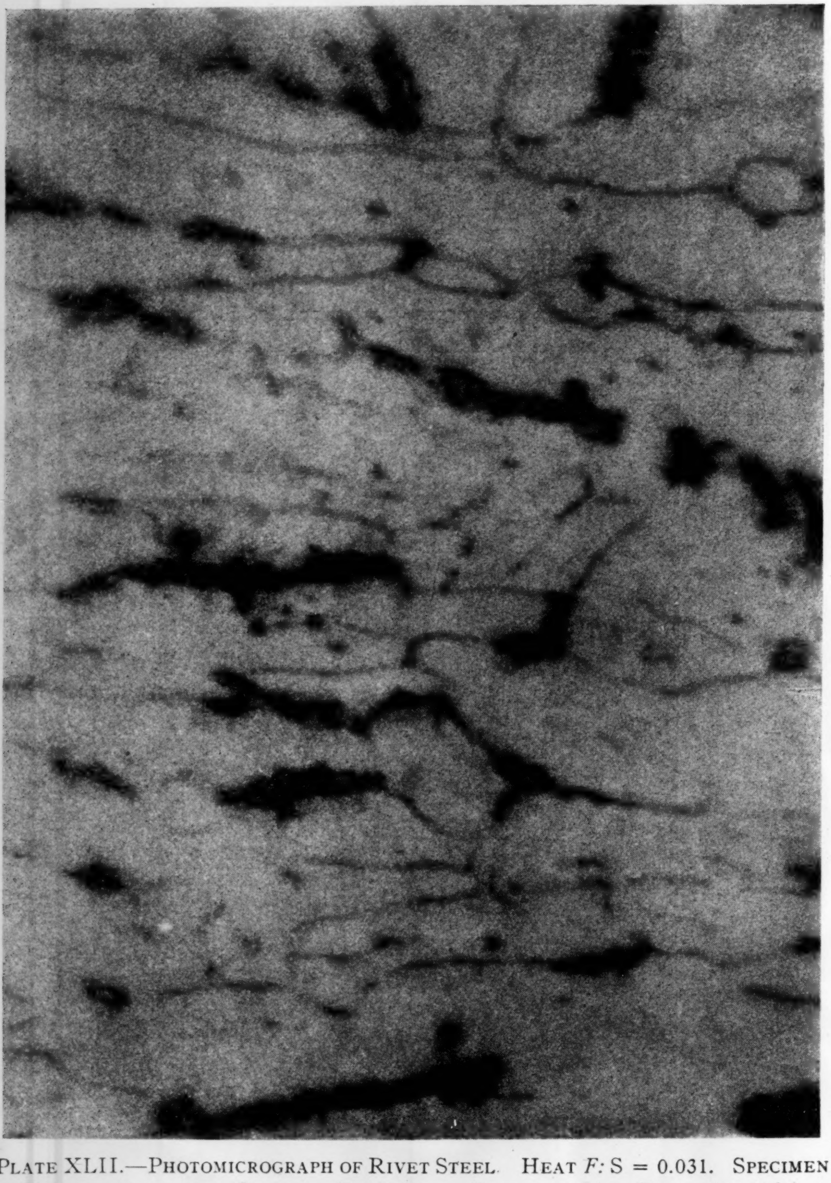


PLATE XLII.—PHOTOMICROGRAPH OF RIVET STEEL. HEAT *F:* S = 0.031. SPECIMEN HEATED ABOVE THE CRITICAL RANGE AND COOLED IN AIR BLAST (× 4000). (For Micrograph × 1000 see Pl. XXVI, Fig. 48.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: C-4.
Exposure: 4 minutes, 13 seconds.

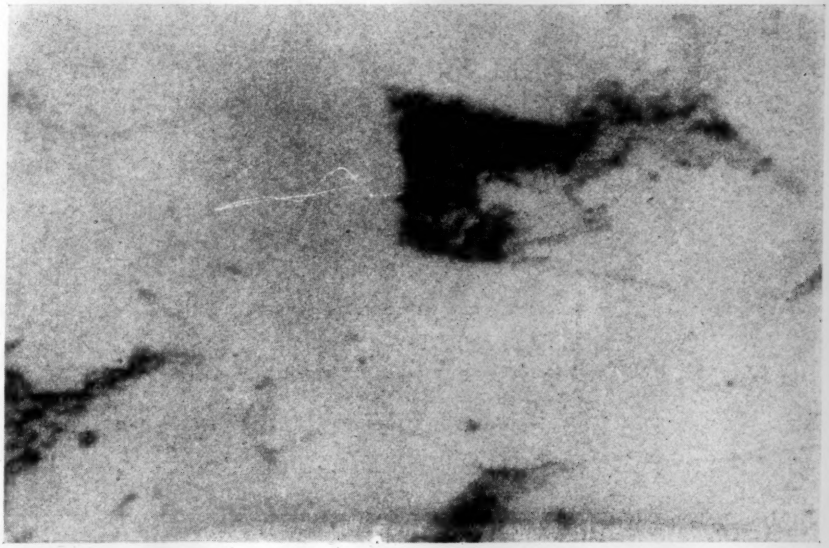


FIG. 53.—Heat *R:* S = 0.083.
(For Micrograph × 1000 see Pl. XXVI, Fig. 49.)

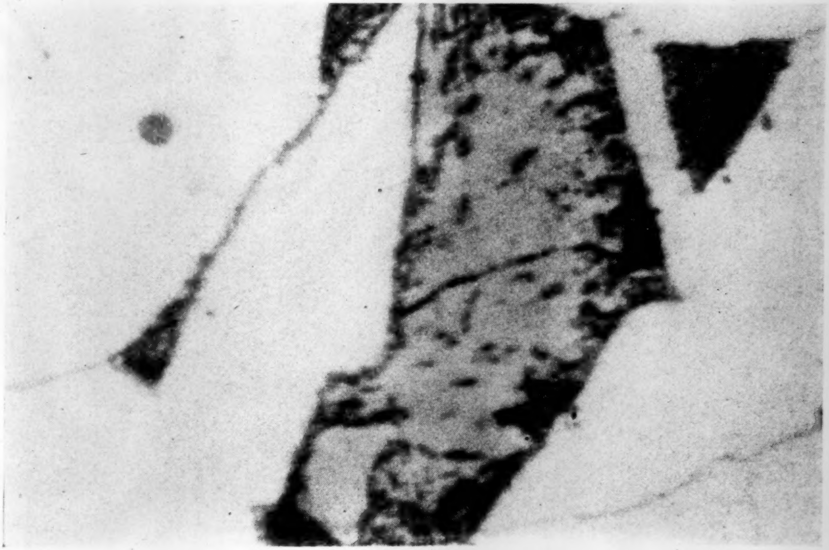


FIG. 54.—Heat *M:* S = 0.179.
(For Micrograph × 1000 see Pl. XXVI, Fig. 50.)

PLATE XLIII.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND COOLED IN AIR BLAST (× 4000).

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

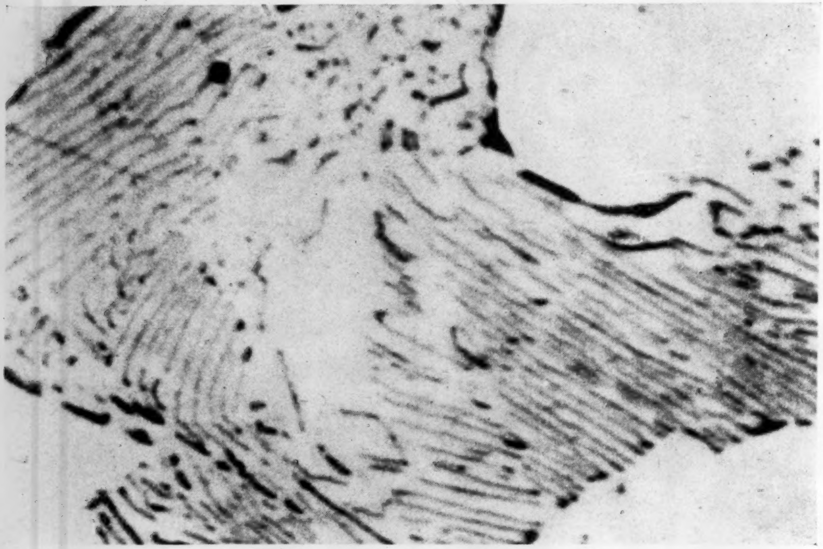


FIG. 55.

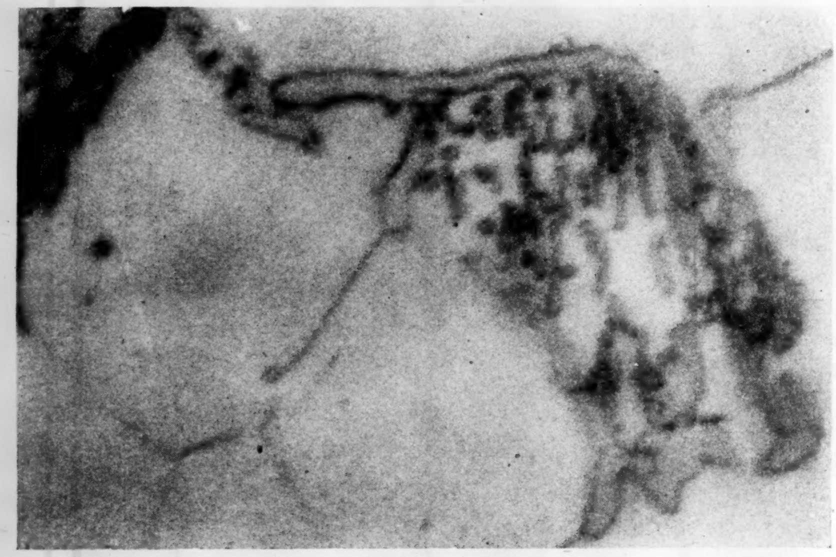


FIG. 56.

PLATE XLIV.—PHOTOMICROGRAPHS OF RIVET STEEL. HEAT *A*: S = 0.028. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND COOLED IN FURNACE (× 4000).

(Micrographs × 1000 not shown.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

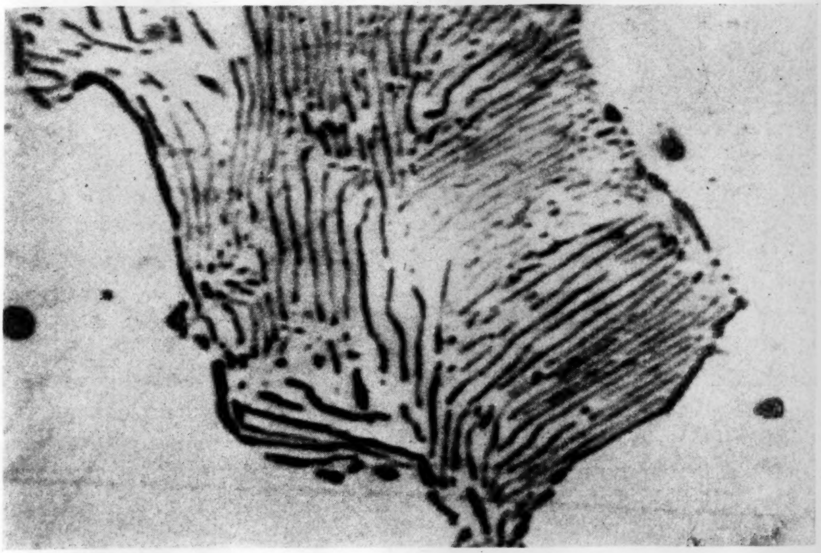


FIG. 57.—Heat *R:* S = 0.083.

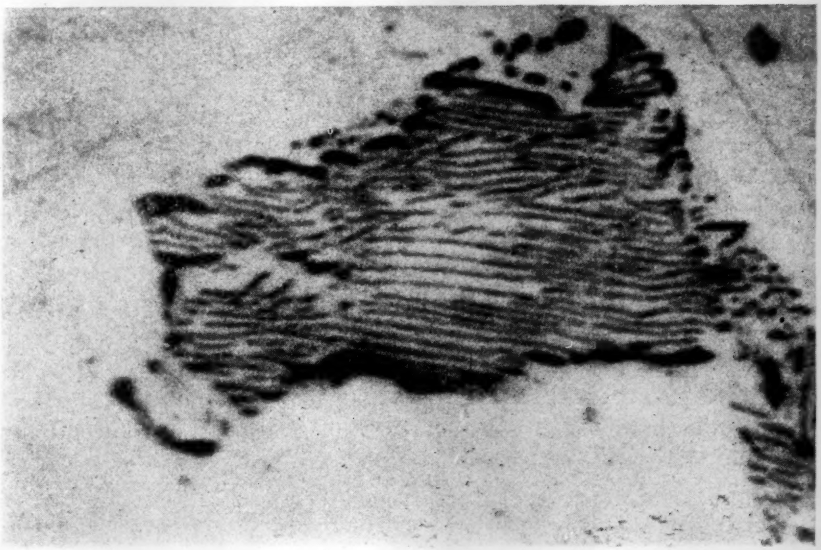


FIG. 58.—Heat *M:* S = 0.179.

PLATE XLV.—PHOTOMICROGRAPHS OF RIVET STEEL. SPECIMENS HEATED ABOVE THE CRITICAL RANGE AND COOLED IN FURNACE (× 4000).

(Micrographs × 1000 not shown.)

Etch: 1-per-cent HNO_3 in alcohol.
Objective: B. & L. 2-mm. apochromatic.
Eyepiece: B. & L. compensating × 18.
Filter: K-1.
Exposure: 2 minutes, 55 seconds.

tendency is evidently greatest at the boundaries of the areas of pearlite. It is especially noticeable in the high-sulfur steel shown in Plate XLV, Fig. 58. The spheroidization of cementite is accompanied by advancement of the boundaries of the ferrite grains surrounding the area of pearlite. Even in furnace-cooled specimens, therefore, the proportion of carbide complex to free ferrite is greatly influenced by variation in the tendency of ferrite grains to grow.

Variation in the microstructure of these rivet steels, therefore, with increase in percentage of residual sulfur is due to variation in total growth of ferrite grains. In a set of specimens cooled at the same time through the critical range, the total growth of the ferrite grains is greater the higher the percentage of residual sulfur. This does not mean that the individual ferrite grains are necessarily larger the higher the percentage of residual sulfur. As mentioned in the description of microstructures observed at 100 magnification, the ferrite grain size in air-cooled and furnace-cooled specimens is smaller and the proportion of free ferrite is larger the higher the percentage of residual sulfur. This would seem to indicate that at least after these relatively slow rates of cooling, rapid ferrite grain growth has proceeded from more nuclei in high-sulfur than in low-sulfur steels.

Microstructural and Thermal Changes in Low-Carbon Steel in Cooling from Above the Critical Range.—Microstructures such as those found in the rapidly cooled rivet steels would be produced if during the cooling the fine cementite particles were deposited uniformly throughout the ferrite and if many of these particles were then swept together by the advancing boundaries of growing ferrite grains. If some of the ferrite grains had grown at the expense of adjacent grains and if in this growth the advancing boundaries had pushed ahead of them the cementite particles that were in their path, this process would have caused the above described definitely bounded areas of closely crowded cementite particles. That such processes have actually been at work may appear probable, if consideration be given to microstructure alone. This conclusion, however, must be considerably modified if consideration be given to the thermal and other physical changes that occur during the cooling of low-carbon steel.

The thermal changes that occur during the slow heating and cooling of steel have been thoroughly studied by many investigators. In their investigations time and temperature records have been made during the heating and cooling of steel and have been expressed in the form of heating and cooling curves. The evidence thus obtained when combined with the evidence obtained by microscopic examination may be expressed in the well-known equilibrium diagrams in which ordinates represent temperatures and abscissas represent chemical composition.

In Fig. 59 is shown an equilibrium diagram representing the microstructural changes that occur during the slow cooling of steel

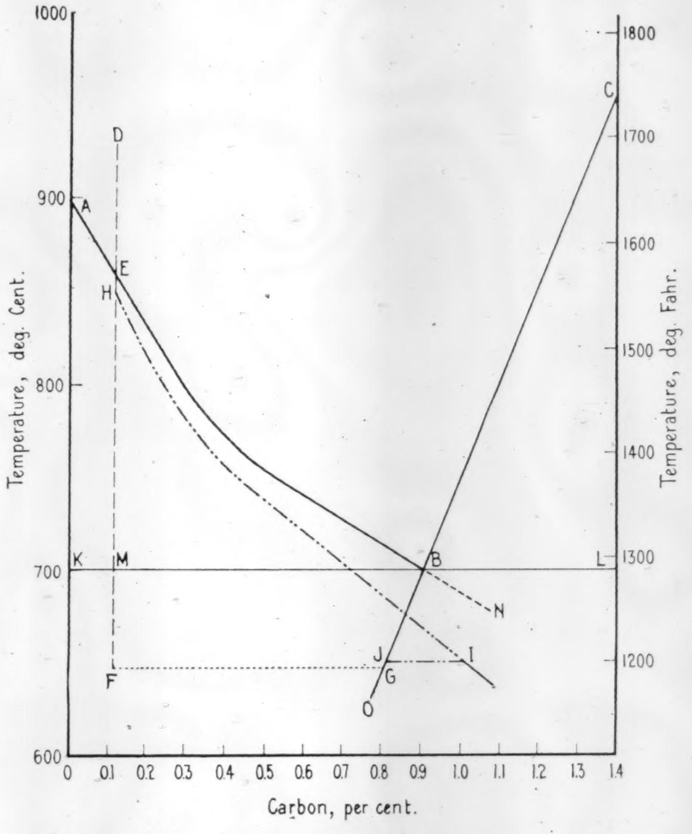


FIG. 59.—Diagrams Representing Micro-structural Changes in the Cooling of Low-Carbon Steel.

through the critical range. To this diagram have been added lines representing, qualitatively at least, microstructural changes that occur during the rapid cooling of rivet steel. In Fig. 59, the lines *EB* and *BC* represent the lower temperature limits of the austenite field in slowly cooled steel. When a specimen of rivet steel is at a temperature of 940° C. (1725° F.) (the quenching temperature used in the heat treatment of the specimens illustrated by the photomicrographs), it may be represented in Fig. 59 by the point *D*. At this temperature, as shown in the figure, the microstructure consists of austenite. When this specimen is slowly cooled ferrite begins to be deposited when the temperature reaches the degree represented by the point *E*. On further cooling the composition of the austenite changes with temperature so that at any instant its temperature and composition would be represented by a point on the line *EN*. When the moving point representing temperature and composition of the austenite crosses the line *CO*, cementite begins to be deposited with the ferrite and the temperature and composition remain at the point represented by *B* until all the remaining austenite has been transformed to pearlite.

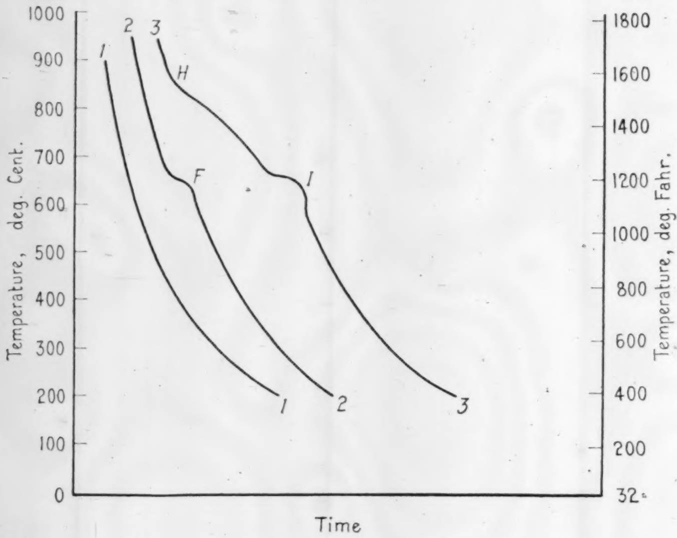


FIG. 60.—Graphs of Thermal Changes in the Rapid Cooling of Low-Carbon Steel.

As shown in Fig. 59, the point *E* at which ferrite first appears in rivet steels is about 150° C. above the point *B* at which cementite appears. The free ferrite found in slowly cooled rivet steels, therefore, was deposited throughout a range of 150° C. before the pearlite appeared. This fact makes it appear possible that in the rapidly cooled rivet steels also the free ferrite was formed before the carbide complex and hence that the free ferrite grains were formed at the expense of adjacent austenite rather than at the expense of adjacent ferrite grains.

There is an additional reason, however, for doubting that in the rapidly cooled rivet steels any grains of ferrite have grown appreciably at the expense of ferrite of the carbide complex. In an investigation at the Naval Engineering Experiment Station,[1] it was shown that the mobility of ferrite grains decreases rapidly from the Ar_3 point to about 1400° F. (760° C.) and that below 1300° F. the mobility is very slight. It therefore seems probable that during quenching all appreciable growth of ferrite grains is completed before any cementite particles appear.

The fact that in slow cooling of rivet steels the formation of ferrite starts about 150° C. higher than the formation of cementite, does not make it certain that in rapid cooling any such temperature range of free ferrite formation exists. There are, however, results of some actual experiments from which conclusions may be drawn regarding this temperature range in rapidly cooled steels. Investigations of the thermal changes in rapidly cooled steels have been comparatively few. The subject has been investigated by Le Chatelier,[2] by Benedicks,[3] and by Portevin and Garvin.[4] The latter investigators made time and temperature observations during the quenching of steels having 0.33 to 1.45 per cent carbon, and during the air cooling of steels having 0.10 per cent carbon. The cooling curves thus obtained have thrown much light on the changes that take place during the rapid cooling of steel. As shown by these curves, with increasing rapidity of cooling both the Ar_3 and Ar_1 points are depressed below the values obtained with slow cooling. The Ar_1 point, which with slow cooling appears at about 700° C. (1292° F.) can with rapid cooling be depressed to about 630° C. (1166° F.). When, however, the quenching rate, with steels having 0.33 to 1.45 per cent carbon, is increased beyond a definite critical rate, the Ar_1 point instead of being lowered below 630° C. disappears entirely. Instead of the Ar_1 point a deviation of the curve appears at about 300° C. (572° F.). Below this critical rate the structure is troostitic, above this rate it is martensitic.

In Fig. 60, curve No. 1 illustrates typical results obtained when the critical rate of quenching is exceeded. Curves Nos. 2 and 3 illustrate the thermal changes that occur in hypo-eutectoid steel when the cooling rate is below the critical value. In curve No. 1

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[1] D. J. McAdam, Jr., "Grain Size of Iron as Affected by Temperature," *Proceedings*, Am. Soc. Testing Mats., Vol. XVIII, Part II, p. 68 (1918).

[2] Le Chatelier, *Revue de Metallurgie*, Vol. I (1904).

[3] Benedicks, *Journal*, Iron and Steel Inst., No. II (1908); also *Revue de Metallurgie*, Vol. VI (1909).

[4] A. M. Portevin and M. Garvin, "The Experimental Investigation of the Influence of the Rate of Cooling on the Hardening of Carbon Steels," *Journal*, Iron and Steel Inst., Vol. XCIX, No. I, p. 469 (1919).

there is no deviation indicating cementite formation. Curves Nos. 2 and 3 show deviation at about 630° C. indicating formation of carbide complex.

The investigations of Portevin and Garvin did not include quenched low-carbon steels. Since low-carbon steels, however, do not form martensite, the critical quenching rate for such steels is evidently above that available in any practicable heat treatment. It seems evident, therefore, that in the quenching of low-carbon steels the Ar_1 point cannot be depressed below about 630° C. (1166° F.).

Portevin and Garvin did not pay so much attention to the position of the Ar_3 point under various conditions as to the position of the Ar_1 point. Nevertheless, they discuss in a general way the influence of various conditions on the cooling curves of rapidly cooled hypoeutectoid steels above the Ar_1 point. Their conclusion is that the formation of ferrite between the Ar_3 and Ar_1 points is greatly influenced by the presence or absence of nuclei of ferrite and by the non-metallic inclusions always present. They state that "the presence of inclusions is known either by their physical action (Ziegler[1]) or by their chemical action (Giollitti[2]) to be a determining cause of the formation of ferrite or of cementite from the commencement of cooling; it will, therefore, influence the critical rate of quenching."

The idea involved in the conclusions of Portevin and Garvin, and of Giollitti, may be illustrated by curves Nos. 2 and 3 of Fig. 60. If no nuclei were present in a rapidly cooled specimen of low-carbon steel, the time-temperature curve would be as illustrated by this curve No. 2. As illustrated by this curve no ferrite would appear until the Ar_1 point is reached and then a complex of ferrite and cementite would appear. In such a specimen there would be no Ar_3 point. If numerous nuclei were present in a rapidly cooled specimen, ferrite would appear at a temperature slightly below the Ar_3 point of slowly cooled steel as illustrated by the change of direction at the point *H* of curve No. 3. The heat evolution due to the formation of this ferrite would retard the cooling so that the portion of the curve between *H* and *I* would be less steep than the portion of curve No. 2 above Ar_1.

Although it is improbable than any specimen of low-carbon steel ready for quenching is entirely free from nuclei, there are evidently in some specimens many regions that are practically free from such nuclei. In such regions when rapidly cooled, free ferrite does not form and the microstructure after cooling consists of a complex of ferrite and cementite having the average chemical composition of the entire specimen. In regions that at the quenching temperature contain many nuclei, the microstructure even after quenching contains free ferrite in addition to areas of carbide complex.

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[1] Ziegler, "Sur la Crystallisation du Fer Alpha," *Revue de Metallurgie*, Vol. 8, No. 9, September, 1911.

[2] F. Giollitti, "Heat Treatment of Soft and Medium Steel," First Edition, 1921, published by McGraw-Hill Book Co.

A study of the thermal changes that occur during the rapid cooling of low-carbon steel, therefore, leads to the conclusion that in the rivet steels whose microstructures have been described, the ferrite found in varying proportions was formed before the carbide complex appeared. The proportion of free ferrite and its distribution in these specimens evidently depends on the number and distribution of nuclei of some kind. The growth of these ferrite grains was at the expense of austenite and not at the expense of ferrite grains of the carbide complex. There were no cementite particles, therefore, in the paths of these advancing grain boundaries. The areas of agglomerated cementite particles that are found on the ferrite grain boundaries must, therefore, be otherwise explained.

In the cooling of hypo-eutectoid steel through the critical range, as the ferrite increases in quantity, the percentage of carbon increases in the layers of austenite adjacent to the ferrite. In slow cooling, diffusion of carbon from the enriched layers adjacent to the ferrite tends to equalize the carbon concentration throughout the austenite. In rapid cooling, however, diffusion of carbon in the austenite is inhibited, so that only the layers adjacent to the ferrite are enriched in carbon content as the ferrite grains grow. These enriched layers in rapid cooling become super-saturated with cementite until a sudden deposition of a number of fine cementite particles restores some semblance of equilibrium. This accounts for the areas of agglomerated cementite particles on the ferrite grain boundaries of rapidly cooled rivet steel.

The changes that occur during the rapid cooling of regions affected by ferrite nuclei may be illustrated qualitatively by the graph *DHIJ* of Fig. 59. The rivet steel specimen at the beginning of quenching is represented in temperature and composition by the point *D*. During quenching the region affected by a nucleus is under-cooled only slightly below the line *AB* before separation of ferrite begins. Starting at a temperature represented by *H*, deposition of ferrite progressively enriches in carbon content the layer of austenite adjacent to the ferrite. This progressive enrichment of the austenite as the temperature falls may be represented by a point moving from *H* along the line *HI*. When this moving point reaches the line *BO*, the austenite is saturated with cementite. After the line *BO* has been crossed, the austenite becomes increasingly supersaturated with cementite. Considerable supersaturation can thus occur with rapid cooling. A point, which may be represented by *I*, is soon reached, however, when deposition of cementite begins and proceeds with evolution of heat and rapid reduction of carbon content of the austenite until the line *BO* has been reached at the point *J*. Deposition of cementite, as represented by the line *IJ*, in relieving the supersaturated condition of the austenite, forms the areas of agglomerated cementite particles appearing adjacent to the ferrite in the above described photomicrographs of rapidly cooled rivet steel.

In regions unaffected by nuclei the effect of rapid cooling may be illustrated qualitatively by the graph *DFG* of Fig. 59. As the temperature falls in quenching from the point *D* no ferrite appears and the austenite remains unchanged in composition until a temperature represented by *F* in Figs. 59 and 60 is reached. At this point is formed a complex of ferrite and cementite having the same average composition as the original austenite. It is possible that in the formation of this complex, minute scattered ferrite grains are formed first, thus raising the carbon content of the remaining scattered austenite grains to a point represented by *G*, at which point ferrite and cementite separate simultaneously. The essential fact, however, is that in regions unaffected by nuclei, the austenite in rapid cooling is transformed into a complex of ferrite and cementite of about the same chemical composition as that of the entire specimen.

In the rapidly cooled rivet steels, therefore, there are two kinds of microstructure. The type of microstructure in any region depends on the presence or absence of nuclei of some kind in the region at the time of quenching. A region affected by nuclei consists of ferrite grains with adjacent layers of agglomerated cementite. A region unaffected by nuclei consists of carbide complex of the same chemical composition as that of the entire specimen. In low-sulfur rivet steels the non-nuclear structure predominates. In high-sulfur rivet steels the nuclear structure predominates. In the rivet steels manufactured for the Joint Committee, therefore, the proportion of nuclear structure increases with increase of residual sulfur.

In the rivet steels manufactured for the Joint Committee, the microstructures are greatly influenced by the number and distribution of nuclei of some kind. In these steels the number of nuclei are approximately proportional to the percentage of residual suulfr. It would not be safe to assume on this evidence, however, that in all steels the number of nuclei varies as the sulfur content, nor would it be safe to assume that a large number of nuclei cannot be found in steels of low-sulfur percentage.

Since the microstructures of rivet steels manufactured for the Joint Committee are evidently influenced greatly by the number and distribution of nuclei of some kind, it becomes of interest to inquire into the nature of these nuclei and also to inquire whether such nuclei are of importance in steel from other sources and of higher carbon content. In considering this subject, the normal and abnormal steels for case-hardening purposes described by Ehn are at once brought to mind. In such steels the carbon content is not much greater than in rivet steels. As described by Ehn,[1] the grain size of "abnormal" steel is smaller than that of normal steel. He does not devote much attention, however, to the behavior of the low-carbon steel itself under heat treatment, but discusses chiefly the results obtained by case-carburizing and case-hardening normal and abnormal steels. He finds that abnormal steel after case carburizing has a thinner case with higher carbon percentage at the outer surface than does normal steel. When hardened, the outer layer of abnormal steel is troostitic and therefore much softer than the martensitic outer layer of normal steel.

When requested, Mr. Ehn kindly sent some samples of normal and abnormal steel to be investigated at the Naval Experiment Station as were the rivet steels for the Joint Committee. These samples, when heat treated as were the rivet steels, were found to differ greatly in microstructure. The difference may be summarized by saying that the abnormal steel behaves like one of the high-sulfur rivet steels and the normal steel behaves like one of the low-sulfur rivet steels that were manufactured for the Joint Committee.

The chemical composition of each of these samples as given by Mr. Ehn is listed below:

	ABNORMAL STEEL	NORMAL STEEL
Carbon, per cent	0.17	0.18
Manganese, "	0.49	0.56
Phosphorus, "	0.013	0.017
Sulfur, "	0.029	0.030
Silicon, "	0.11	0.08
Chromium, "	0.10	nil

It is evident that the difference between these samples of steel is not due to difference in sulfur content. In this "abnormal" sample with low-sulfur percentage the number of nuclei is large.

Not only in low-carbon steels is the influence of nuclei apparent. Frequently, in the microstructure of a medium-carbon steel there are visible regions in which the ferrite tends to persist and to return after long continued heat treatment. Such regions are sometimes in the form of bands or "ghosts," sometimes, especially in castings, they are dendritic in form or of the Widmanstätten type. Such microstructures are frequently found in steels having low percentages of sulfur and phosphorus. The persistence of these ferrite regions in some steels has been the subject of much discussion and has been attributed to various widely differing reasons.

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[1] E. W. Ehn, "Influence of Dissolved Oxides in Carburizing and Hardening Qualities of Steel," *Journal*, Iron and Steel Inst., No. 1 (1922).

The theories regarding the nature of these nuclei may be grouped in two divisions. One group of investigators believes that a nucleus is not a distinct phase but is a region in which some element or compound is segregated in solid solution in the ferrite. Stead,[1] for example, presents evidence that phosphorus in segregated solid solution in the ferrite is responsible for ghost lines and other regions in which ferrite tends to appear even after repeated heat treatment. According to Stead's explanation, carbon and phosphorus each decrease the solubility of the other in austenite. Hence as an austenite region rich in phosphorus cools through the critical range, carbon is repelled from this region and ferrite is deposited. In his more recent paper[2] on this subject the evidence presented as to the mutual influence of phosphorus and carbon appears conclusive. These conclusions, however, have been disputed by other investigators. Le Chatelier and Bogitch,[3] for example, assert that there is no evidence that phosphorus causes ghost lines. They present evidence that oxygen segregated in solid solution is the cause of these persistent ferritic regions.

A second group of investigators believes that a nucleus is a distinct phase consisting either of a non-metallic inclusion or a particle of pro-eutectoid constituent that has not been dissolved when heated above the critical range. According to Ziegler's[4] explanation such a particle in steel has the same physical effect that a crystal of sodium sulfate has when dropped into a supersaturated aqueous solution of the same salt. He believes that such nuclei inoculate the solid solution of austenite and result in the persistent reappearance of ferrite around each nucleus.

Although Ziegler's theory of the physical effect of nuclei still has its advocates, a modified theory of the action of particles of distinct phase has been adopted by Giollitti[4] and others. According to Giollitti, non-metallic inclusions of some kinds in steel, by the chemical action of oxygen continually diffusing from them into the steel, surround themselves with a layer deficient in carbon, and this low-carbon region acts as a nucleus for deposition of ferrite from the austenite. According to this view, non-metallic inclusions act as reservoirs for the dissemination of oxygen into the surrounding steel, and these regions of altered metal act as nuclei for deposition of ferrite.

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[1] J. E. Stead, "Iron, Carbon and Phosphorus," *Journal*, Iron and Steel Inst., No. I (1915).

[2] J. E. Stead, "Iron, Carbon and Phosphorus," *Journal*, Iron and Steel Inst., No I (1918).

[3] H. Le Chatelier and B. Bogitch, "Macrogrophie des Aciers," *Revue de Metallurgie*, No. 2, p. 129 (1919).

[4] *Loc. cit.*

Ehn[1] is of the opinion that the abnormality of some samples of steel for case hardening is caused by excess of oxides due to improper deoxidation in the manufacture of the steel. He does not make it clear, however, whether he regards the oxides as in solid solution or as a distinct phase. Sometimes he refers to them as solid solutions, sometimes as inclusions, and sometimes as colloidal solutions. Since he states that austenite also is probably a colloidal solution, one is not left with a clear idea of his views as to the nature of the nuclei. He considers it proved, however, that the abnormality is due to oxides.

There seems to be no good reason to assume that all nuclei in steel are of the same kind. It seems quite probable that in some steels the regions of persistent ferrite segregation are due, as Stead says, to phosphorus segregation in solid solution rather than to particles of distinct phase. It also seems probable that in other steels the regions of persistent ferrite are due to particles of distinct phase, such as non-metallic inclusions, which either directly by their physical effect or indirectly by their chemical action serve as nuclei for the deposition of ferrite. If such inclusions act as reservoirs from which oxygen radiates into the surrounding metal, the influence of an inclusion in promoting deposition of ferrite can readily be understood. That such inclusions would act as nuclei for the deposition of cementite, however, is not so apparent. Yet, as described by Ehn, his abnormal steel showed its abnormality most clearly in the hyper-eutectoid case. In this outer layer after slow cooling the pearlite was found to be more or less broken up into independent ferrite and cementite. After quenching, the outer layer was found to be troostitic rather than martensitic. This behavior of the hyper-eutectoid case would seem to point to physical rather than chemical action of some element or compound either in solid solution in the ferrite or as a distinct phase.

The results of the above described metallographic examination of rivet steels do not make it possible to decide as to the nature of the nuclei. There is one fact, however, which would seem to indicate that in these steels the nuclei are more nearly proportional to the total number of non-metallic inclusions rather than to the sulfur content. As mentioned above, a specimen of the set that had been cooled in an air blast was found to have a microstructure like that of specimens with considerably less sulfur. This specimen from heat *C*, having 0.044 per cent sulfur, has a network structure, while specimens on each side of it in the series have a granular structure. In searching for the reason for this abnormality, it was found that heat *C*, had been rated by several observers as having a smaller quantity of inclusions than any of the other heats (see Table IV). This, however, may be merely a coincidence, since in the sample of abnormal steel submitted by Mr. Ehn no more inclusions are visible under the microscope than in the sample of normal steel. It is possible that the microstructure depends more on a relatively large number of sub-microscopic inclusions than on the relatively small number of visible inclusions. The number of sub-microscopic inclusions is not necessarily proportional to the number of visible inclusions.

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[1] *Loc. cit.*

The investigation of the microstructure of rivet steel, therefore, has shown that in these heats of steel, manufactured at the same plant and at about the same time, the nuclei on which ferrite tends to deposit in cooling are approximately proportional to the percentage of residual sulfur. No definite conclusions can be drawn at this time as to the nature of these nuclei. Similar nuclei apparently exist in large numbers in heats of abnormal hypo-eutectoid steels that do not contain a high percentage of sulfur. The nuclei, therefore, evidently do not always depend on sulfur content. In the rivet steels manufactured for the Joint Committee, however, increase in the number of nuclei followed the variations in the manufacturing process which resulted in increase of percentage of sulfur.

When the metallographic investigation by the Joint Committee of additional groups of material has been completed, it may possibly throw more light on the nature of the nuclei.

Respectfully submitted on behalf of the Joint Committee,

GEORGE K. BURGESS,
Chairman.

C. L. WARWICK,
Secretary.

DISCUSSION

Mr. Comstock.

Mr. George F. Comstock[1] (*by letter*).—Mr. McAdam has performed a valuable service for metallographists in presenting this detailed study of the meaning of a sulfur print. His conclusion that it "does not always give a reliable indication of even the qualitative distribution of sulfur in a section of steel" is, however, in the writer's opinion only partially justified. If it is assumed that every type of coloration on a sulfur print should be due to sulfur, then the above statement is probably correct. But in our experience with sulfur printing, we have found that these prints show two kinds of markings, dark brown or black spots, and lighter brown tones which are spread over larger areas. We have come to the conclusion that a sharply defined dark brown or black spot on a properly made sulfur print invariably represents a group of segregated sulfide inclusions, while the variations in tone of the lighter brown background of the print are usually due to something else besides sulfur. If sulfur prints are interpreted in this way, I do not think that Mr. McAdam's condemnation of their reliability is justified.

It may be that the two types of markings mentioned above would not always be readily distinguished with all methods of sulfur printing. Our practice is to use 3-per-cent sulfuric acid, with Azo Paper, Grade A, Hard, and to make three prints from each sample. The second print is normally the best. The first one shows the black spots due to sulfur very prominently, but the markings are apt to be poorly defined. The third one shows the brown coloration, due to something else, most distinctly. I do not know how these results would be affected by the use of 5-per-cent acid, or with other kinds of paper.

It is certain that carbon in the steel is one of the factors affecting the brown tone, for low-carbon steel invariably gives a lighter print than higher-carbon steel, with the same time of contact in printing, and irrespective of sulfur content. It is equally certain, however, that other factors also affect this coloration, for titanium-treated rail steel nearly always gives darker prints than rail steel of similar chemical composition but not treated with titanium. The accompanying illustration (Fig. 1) shows an unusual case of the dark coloration around the edge of a rail section. This was the third print from an A-rail showing considerable segregation. The sulfur con-

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[1] Metallurgical Engineer, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

Mr. Comstock. tent of the dark brown areas at the top of the head was 0.018 per cent; at the center of the head it was 0.021 per cent; and at the middle of the web, where the black spots are largest and most thickly segregated, it was 0.028 per cent. The cause of the dark coloration around the edge of this sulfur print was not discovered in a metallographic examination of the steel, and it is very rarely found in rails in this pronounced form. Prints taken from several different sections of this rail all showed the same effect, however, so that it could not be due to any peculiarity of manipulation in making this print. Probably the distinction between the brown outer layer and the black spots representing segregation at the middle of the web will be lost in reproducing this print for publication, but it should as a rule be possible to make this distinction on the original prints so as to avoid being misled in regard to the actual segregation of sulfur shown.

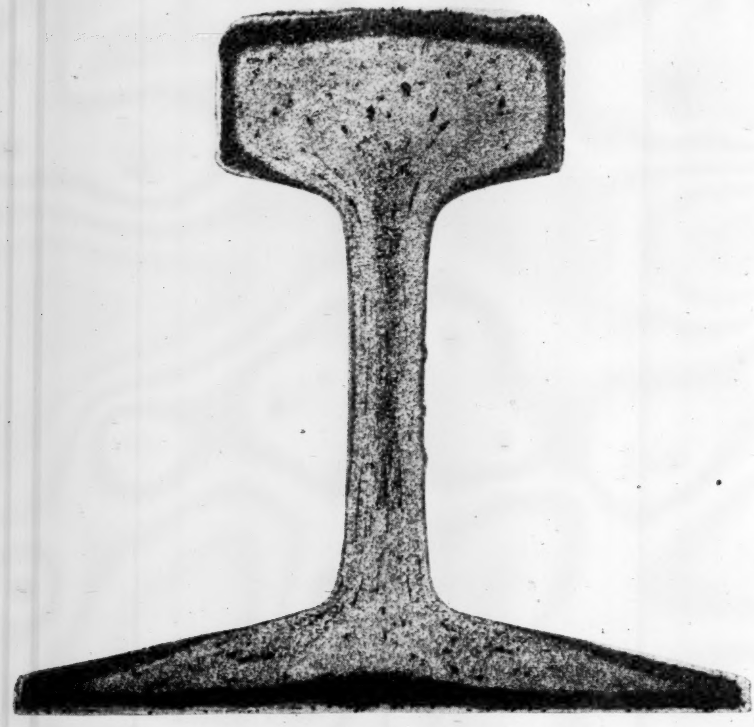

FIG. 1.— Sulfur Print of Rail Section.

Mr. Comstock.

It seems somewhat unfortunate, in view of the great care used in studying the structures of these samples, that more definite information was not secured as to the exact part of the ingot represented by each one. It is stated that the samples examined were made from billets comprising 60 per cent of the ingot, but it may be that all came from the bottom of the ingot, where negative segregation would be expected. Or variations in position in the ingot may be the reason for some of the differences shown in macrostructure.

The study of the effect of sulfide inclusions would have been simplified had the use of aluminum been omitted, so that alumina inclusions would not have been present with the sulfides. But even in the presence of alumina, it should have been possible, by proper polishing of the specimens, to grade them on the basis only of the amount of sulfides present instead of considering all inclusions together. Probably heat C, which appeared so free from inclusions in spite of its 0.044 per cent of sulfur content, did not contain so much alumina as the others, as it may be noted that the amount of aluminum used in this heat is not given. The latter part of the paper, discussing the question of nuclei, seems very well worked out, and the conclusions drawn certainly do not go beyond the limits of the facts presented.

Mr. McAdam.

MR. D. J. MCADAM, JR.[1] (*Author's closure by letter*).—Mr. Comstock kindly let me see the sulfur print that he presents with his discussion as illustration of his conclusions. Mr. Comstock believes that in this sulfur print the "brown coloration" in the outer layer of the section is not due to sulfur. He says that it is necessary to distinguish carefully between such "brown coloration" and the "dark brown or black spots" representing sulfide inclusions.

I examined with a low-power lens the "brown coloration" representing the outer layer of the rail section and found that it is made up of distinct spots on a white background. The spots are similar in every way except size and coloration to the dark spots distributed throughout the section. The spots in the "brown coloration" are smaller and more numerous than those in the interior of the section. The average color of these small spots is somewhat lighter than the color of the large spots. The color of each small or large spot shades from dark brown at the center to brownish yellow at the edge. As seen under a low-power microscope there is no reason, therefore, to conclude that the spots that make up the outer "brown coloration" are qualitatively different from the dark spots that Mr. Comstock says are due to sulfide particles.

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[1] Metallurgist, U. S. Naval Engineering Experiment Station, Annapolis, Md.

Mr. McAdam. Mr. Comstock's conclusion that the dark outer layer is caused by something other than sulfur is evidently based on the fact that the percentage of sulfur in this outer layer of the rail head is lower than in the lighter colored interior. I wish to advance a theory, however, that will explain this fact on the well justified assumption that the coloration of the entire sulfur print is due to hydrogen sulfide.

When photographic printing paper is subjected to the action of hydrogen sulfide gas, the coloration varies from brownish yellow through yellowish brown and dark brown to black, the depth depending on the concentration and length of time of action. (The depth of coloration, however, does not increase in proportion to the concentration of silver sulfide.) The above described coloration of the small spots on the sulfur print as observed under a low-power lens could therefore be due to hydrogen sulfide gas.

If it be assumed that the coloration throughout the entire section of the sulfur print is due to hydrogen sulfide gas, the fact that the outer layer of lower sulfur content gives a darker coloration than the interior may be explained as follows. The sulfide particles in the outer layer are smaller but more numerous than the particles in the interior. The hydrogen sulfide gas from each particle makes a spot on the sulfur print considerably larger than the particle itself. Some comparisons made at the Naval Engineering Experiment Station have shown that the diameter of the spot on a sulfur print may be from five to ten times that of the sulfide particle. It will be evident, therefore, that with the same sulfur content the coloration of the print will be darker the smaller the average size of sulfide particle. If there are many small particles the coloration is spread over a larger total area of the print and the print appears darker than if there are a few large particles.

It is believed that this theory explains Mr. Comstock's sulfur print. This sulfur print therefore is additional evidence that occasionally a sulfur print may lead to incorrect conclusions regarding the distribution of sulfur in a section of steel.

EFFECT OF SULFUR ON STRUCTURAL STEEL

FIFTH PRELIMINARY REPORT OF THE JOINT COMMITTEE ON INVESTIGATION OF PHOSPHORUS AND SULFUR IN STEEL[1]

Introduction

This preliminary report of the Joint Committee on Investigation of Phosphorus and Sulfur in Steel deals with the effect of sulfur on structural steel. This material is designated as Group II, Series A, with approximate carbon range of 0.16 to 0.22 per cent, as specified in an earlier report of the committee.[2] Six heats of basic open-hearth steel, varying in sulfur content from approximately 0.03 to 0.08 per cent, were made for this investigation by the Cambria Steel Co., under the immediate direction of the committee. Carbon, manganese and phosphorus were normal for structural steel and were kept as nearly constant as possible. The sulfur was "residual" sulfur, that is, sulfur present in the steel through its presence in the materials charged into the furnace and not through additions made in the ladle or mold. Sufficient material for test was furnished from each heat in the form of universal and sheared plates $\frac{5}{8}$ in. thick.

The material was tested in the natural condition "as received," in annealed condition, in normalized condition and in quenched condition. Tension, impact, hardness, bend and shear tests were made upon specimens with axes respectively parallel and perpendicular to the long dimension of the plate.

One set of material was tested at the laboratory of Watertown Arsenal, Watertown, Mass., and a duplicate set was tested at the laboratory of the U. S. Naval Engineering Experiment Station, Annapolis, Md. With certain exceptions noted later, identical tests were made at the two laboratories. As in the other investigations, methods of testing were prescribed in advance and followed in each laboratory in so far as possible. A triplicate set of material is held in reserve at the U. S. Bureau of Standards.

The magnitude of this phase of the investigation is indicated by the fact that over 85 samples were analyzed chemically for five elements, and something over 1900 physical tests were made.

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[1] Published by permission of the U. S. Bureau of Standards, U. S. War Department and U. S. Navy Department.

[2] For this classification, see *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 136 (1923).

The complete investigation with full descriptive matter will ultimately be published as a technologic paper of the U. S. Bureau of Standards. The Joint Committee, however, desires to make the data available as soon as possible for the information of all interested and to bring out comment and discussion. The present preliminary report is therefore made to the constituent organizations and, with the approval of the Bureau of Standards, the War Department and the Navy Department, will be published in the Proceedings of the American Society for Testing Materials. The report is limited to the presentation of the essential data in graphical form, with only sufficient explanatory text to make the report clear and self-contained. The complete publication will contain tables, photomicrographs, illustrations of specimens and some descriptive matter that are omitted from the present report.

Although the Joint Committee has fully reviewed all the test data herein presented, it has been decided for the present to defer the drawing and publishing of formal conclusions.

The committee wishes to acknowledge its indebtedness to L. R. Custer, Vice-President and General Superintendent of the Cambria Plant, L. H. Winkler, Engineer of Tests, and L. F. Quigg, Open-Hearth Superintendent, who collaborated in the securing of the steel for this investigation; and to N. Richardson and H. C. Mann, who assisted F. C. Langenberg in the tests at Watertown Arsenal, and Lawrence Thompson, who assisted D. J. McAdam in the tests at the Naval Experiment Station.

DESCRIPTION OF MATERIAL

The steel for this investigation was all basic open-hearth structural steel, manufactured in accordance with usual commercial practice, and was made by the Cambria Steel Co. at their Franklin Works, Johnstown, Pa. Four heats (*B*, *C*, *D* and *E*) were made August 31 to September 2, 1921, and two ingots from each heat were held for acceptance of the Committee on Manufacture of the Joint Committee. The committee visited these works October 24 to 27, 1921, accepted these ingots and witnessed their rolling into plates. The committee also witnessed the preparation of heat *A*, but the high sulfur heat, *F*, was not made until May, 1922. Two ingots from heats *A* and *F* were then rolled into plates. Heats of approximately 90 tons were used, material not required for the investigation being routed elsewhere. The Joint Committee has complete data on the manufacture of this steel, including details of charge in the furnace, additions in the furnace and ladle, and temperatures of blooming and rolling. The sulfur in all heats is "residual" sulfur, that is, present in the steel through its presence in the materials charged in the furnace and not through additions made in the ladle or mold. The sulfurs aimed at in the six heats, *A* to *F*, inclusive, were respectively 0.03, 0.04, 0.05, 0.06, 0.07 and 0.08 per cent. The desired carbon range was 0.16 to 0.22 per cent; manganese, 0.35 to 0.40 per cent; phosphorus, low. Following are the manufacturer's check analyses made from drillings on the finished plates:

HEAT LETTER	SULFUR, PER CENT	CARBON, PER CENT	MANGANESE, PER CENT	PHOSPHORUS, PER CENT
A....................	0.033	0.20	0.41	0.012
B....................	0.040	0.22	0.46	0.014
C....................	0.055	0.25	0.47	0.015
D....................	0.055	0.19	0.48	0.015
E....................	0.068	0.19	0.46	0.013
F....................	0.078	0.20	0.47	0.012

The chemical compositions as determined by the Joint Committee are recorded in Table I.

From each heat there were retained for the use of the committee, two ingots 20 by 22½ in. and 25½ by 40 in. in cross-section at the base and weighing 7600 and 16,200 lb., respectively. All of the ingots were top cast. The smaller ingots were rolled into slabs 4 in. thick, and after a top discard of about 35 per cent, were rolled into "universal" mill plate ⅝ in. thick. (In universal mill plate the sides and edges are rolled in one operation and the plate is rolled back and forth without turning.) From each ingot there were secured three universal plates 20 by 96 by ⅝ in. and six plates 15 by 96 by ⅝ in. The larger ingots were rolled into slabs 6 in. thick, and after a top discard of about 40 per cent, were rolled into "sheared" mill plate ⅝ in. thick and 35 in. wide. (In sheared mill plate the edges are not rolled. The sheared mill plate for this investigation was rolled both longitudinally and transversely.) These plates were then sheared longitudinally into plates 15 and 20 in. wide. From each ingot there were secured six plates 20 by 96 by ⅝ in. and six plates 15 by 96 by ⅝ in.

The material in general rolled satisfactorily. In rolling the ingots from three heats of higher sulfur (*D*, *E* and *F*) some slight trouble was experienced from cracked and scabby edges and breaking up. However, all the plates were in good condition, the slabs having been chipped in such manner as to produce practically perfect plates.

One-third of the plates were sent to Watertown Arsenal, one-third to the Naval Experiment Station and the remainder to the Bureau of Standards.

DESCRIPTION OF TESTS

In this investigation, the material was tested in tension, impact (Charpy), hardness (Brinell and scleroscope), bending and shear. Specimens were taken with their axes both parallel and perpendicular to the long dimension of the plate, that is, parallel and perpendicular to the direction of rolling of the "universal" plates and to the principal direction of rolling of the "sheared" plates. Tests of the material were made at both laboratories in the natural condition "as received" and in the annealed condition. At the Naval Experiment Station, the material was tested also in the normalized condition and in the quenched condition. All tests indicated above were made at both laboratories, except that the hardness tests were made only at the Naval Experiment Station.

TABLE I.—AVERAGE CHEMICAL COMPOSITIONS, WITH MEAN DIVERGENCES.

Each value is the average of separate analyses on 14 or more samples from each heat. The heats are arranged in the order of increasing sulfur contents.

Heat Letter	Sulfur, per cent		Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Silicon, per cent
	Volumetric	Gravimetric				
A	0.0345±0.0040	0.032	0.190±0.0088	0.408±0.0093	0.0063±0.0023	0.0078±0.0038
B	0.0425±0.0010	0.041	0.216±0.0155	0.446±0.0135	0.0078±0.0018	0.0160±0.0030
D	0.0590±0.0020	0.059	0.185±0.0055	0.478±0.0100	0.0103±0.0031	0.0103±0.0039
C	0.0595±0.0020	0.057	0.248±0.0100	0.433±0.0145	0.0080±0.0020	0.0090±0.0060
E	0.0693±0.0043	0.063	0.193±0.0100	0.469±0.0048	0.0095±0.0015	0.0288±0.0053
F	0.0763±0.0018	0.0715	0.198±0.0065	0.484±0.0093	0.0103±0.0018	0.0275±0.0055

Chemical Analyses.—At Watertown Arsenal, separate chemical analyses were made on drillings taken from broken tension test specimens, three analyses being made to represent universal and three to represent sheared plate from each heat. At the Naval Experiment Station, separate analyses were made on drillings taken from the ends of the plates and on drillings from the cross-section of each plate at another location, there being usually four analyses made representing each kind of plate for each heat. Sulfur, carbon, manganese, phosphorus and silicon were determined in each analysis. Nickel and chromium were also determined on some of the material from each heat. The methods used were those specified by the American Society for Testing Materials. Sulfur was determined by the volumetric method, and the sulfur contents reported and used in the plotting of the data are "volumetric" percentages. However, some determinations of sulfur by the gravimetric method (at least two determinations per kind of plate per heat) were made at the Naval Experiment Station, and these are reported for comparison.

Heat Treatment.—After the plates had been cut up into "blanks" for the various test specimens, the various "blanks" or pieces requiring heat treatment were treated as follows: In annealing, the material was heated to 870° C. (1600° F.) at Watertown Arsenal and to 900° C. (1650° F.) at the Naval Experiment Station, held for one hour and cooled in the furnace. In normalizing, the material was heated to 870° C. (1600° F.), held for one hour and cooled in air. In quenching, the material was heated to 900° C. (1650° F.), held for one hour and quenched in water at 21 to 23° C. (70 to 73° F.). All machine work on specimens requiring machining was done after heat treatment. That is, all heat treatment was done on the full-size thickness of material.

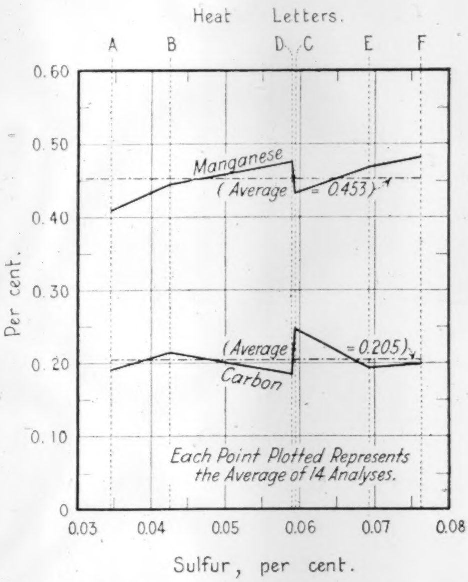

FIG. 1.—Average Carbon and Manganese Contents Plotted Against Average Sulfur Content of Each Heat. (See Table I.)

Specimens.—Tension tests were made upon turned specimens of the largest practicable diameter from the $\frac{5}{8}$-in. material. The specimens at Watertown Arsenal were 0.357 in. in diameter by 1.4 in. in gage length; at the Naval Experiment Station they were 0.357 in. in diameter by 2 in. in gage length. (In the former specimen, the ratio of $\frac{l}{\sqrt{a}}$ is practically the same as that of the standard 2 by 0.505-in. specimen.) The Charpy impact specimens were the same as illustrated in the previous report,[1] that is, the standard 10-mm.

specimen with the "round" notch. The bend test specimens at both laboratories were machined to 1 by ½ in. in cross-section, with corners rounded to a radius of $\frac{1}{16}$ in., and were tested with the 1-in. face against the die block. The shear tests were made on full-size specimens, that is, ⅝ in. thick. Hardness tests were made on the face of the plates. All machine work was done at the respective laboratories.

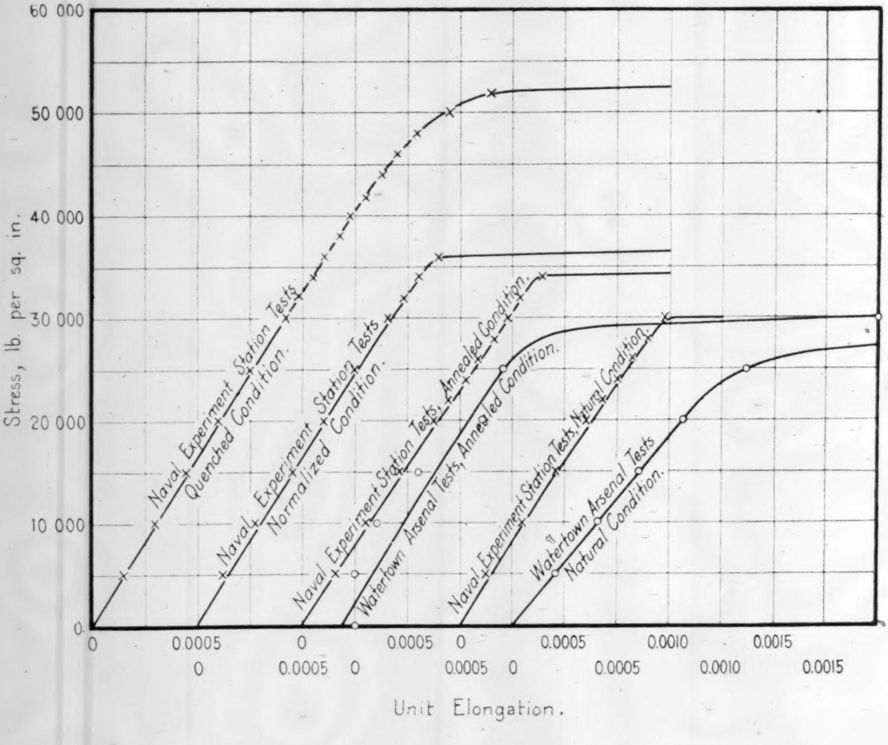

FIG. 2.—Typical Stress-Strain Curves. Material from Heat *B*.

Methods.—In general, the standard methods of the American Society for Testing Materials were followed where applicable. The methods were outlined in the Report on Effect of Sulfur on Rivet Steel,[2] which should be referred to for details.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 100 (1922).

[2] *Ibid.*, p. 101. The Joint Committee calls attention to the fact that the method of making the bend test described in this reference, which has been used by the Committee in bend tests of all material so far studied, is more severe than the usual commercial method in that the initial bending before final flattening is so done as to confine the bending to a shorter length of the specimen than in the usual commercial method. The use of the more severe method is necessary if the test is to distinguish at all between the "resistance to bending" properties of the different steels involved in these investigations.

Number of Tests.—At Watertown Arsenal, three tension, impact, bend and shear tests, respectively, were made for universal plate, both longitudinal and transverse specimens, and for sheared plate, both longitudinal and transverse specimens, for each heat, in both the natural and annealed condition. At the Naval Experiment Station, three tension, four impact, two Brinell and four scleroscope hardness, two bend and three shear tests were made for both kinds of plates, with specimens in both directions, for each heat, in the natural, normalized, and quenched conditions. For material in the annealed condition, the corresponding number of tests were two tension, two impact, two Brinell and four scleroscope hardness, two bend and two shear tests.

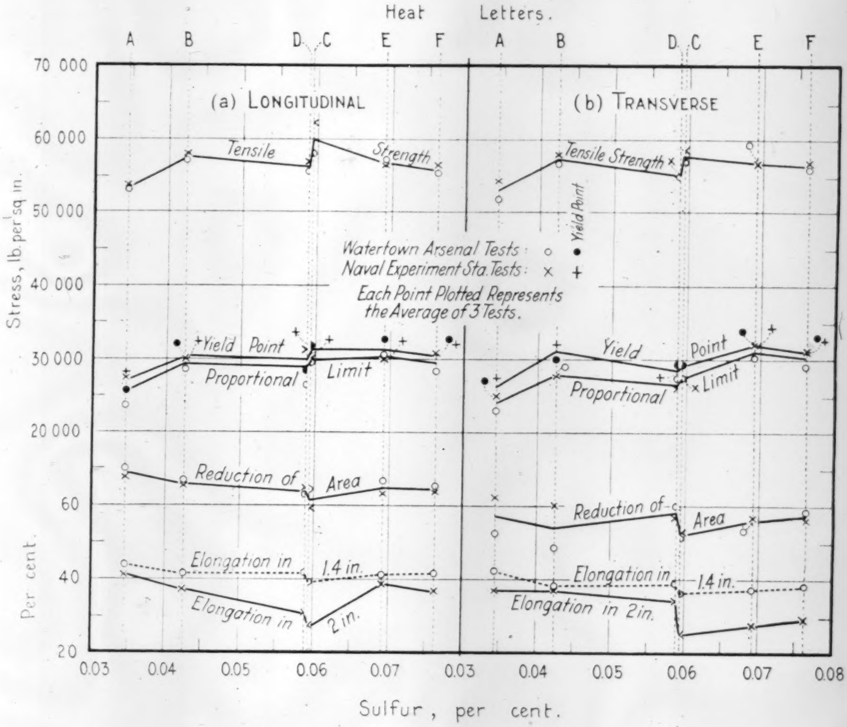

FIG. 3.—Tensile Properties of Universal Plates in Natural Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

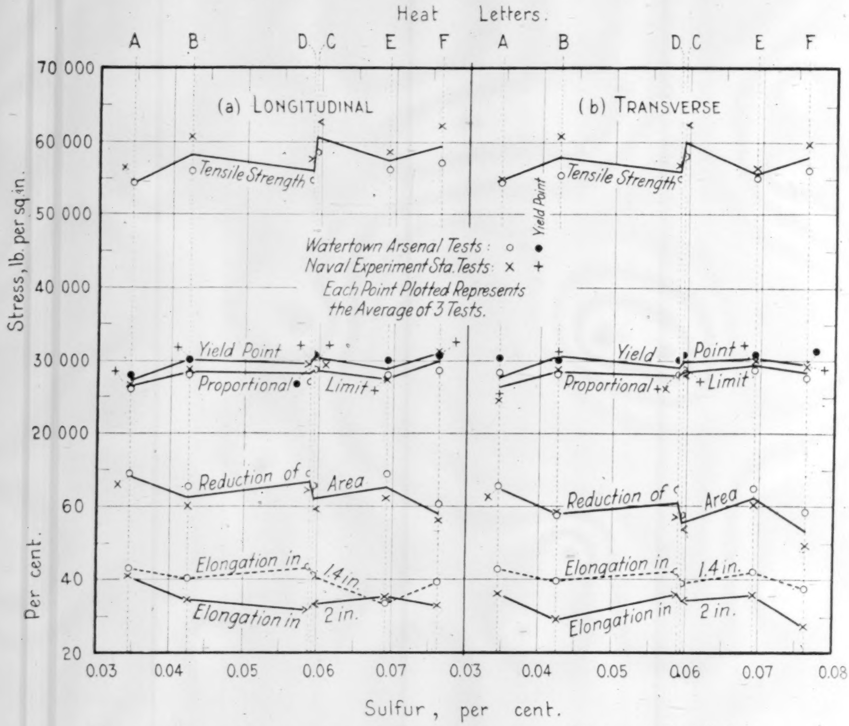

FIG. 4.—Tensile Properties of Sheared Plates in Natural Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

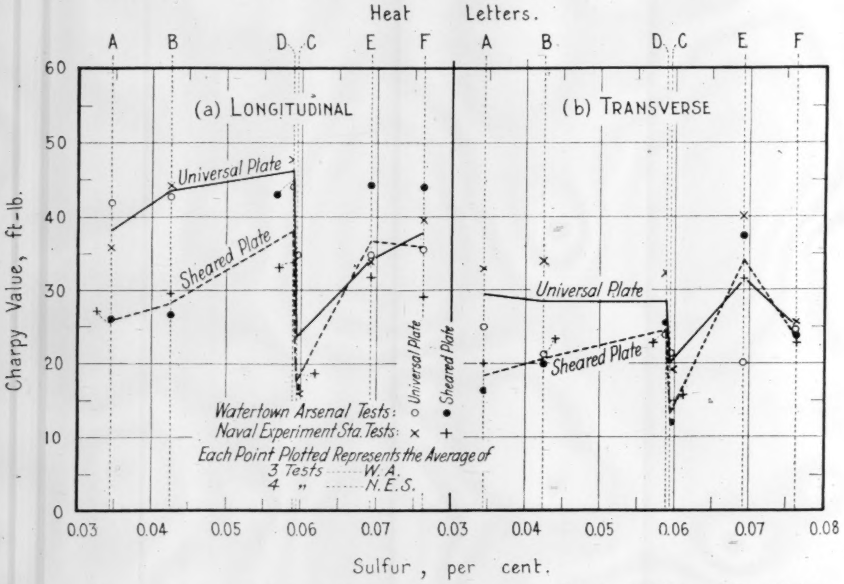

FIG. 5.—Charpy Impact Values of Universal and Sheared Plates in Natural Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

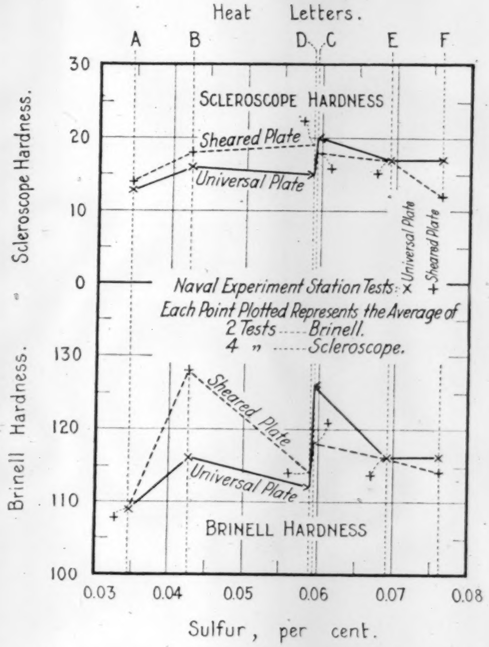

FIG. 6.—Brinell and Scleroscope Hardness Values of Universal and Sheared Plates in Natural Condition.

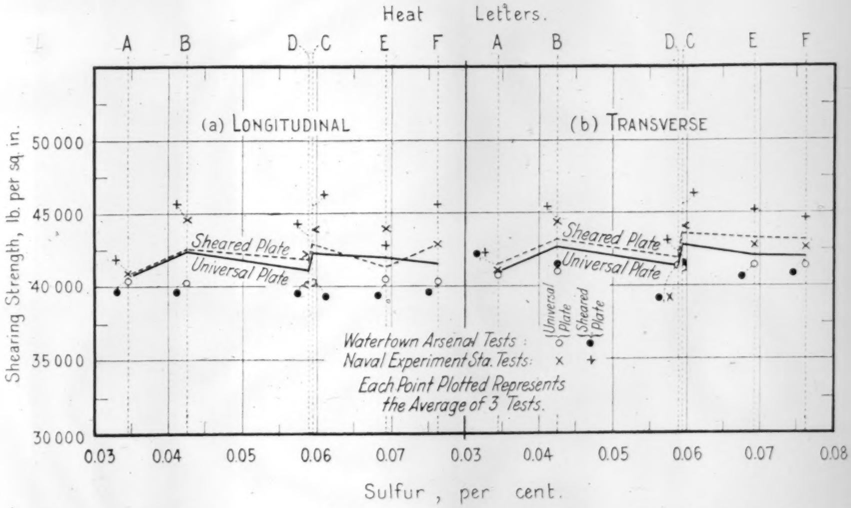

FIG. 7.—Shearing Properties of Universal and Sheared Plates in Natural Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

PRESENTATION OF TEST DATA

As previously explained, three analyses were made at Watertown Arsenal to represent respectively universal and sheared plate, from each heat, and four or more such analyses at the Naval Experiment Station, sulfur, carbon, manganese, phosphorus and silicon being determined in each analysis. In order to obtain a uniform basis for plotting the physical properties, the committee averaged for each heat the average of the determinations at each laboratory and these average values with the mean divergences are given in Table I. The average sulfur content for each heat, as determined by the volumetric method, is used for that heat throughout in plotting the figures. (Some determinations of sulfur by the gravimetric method made at

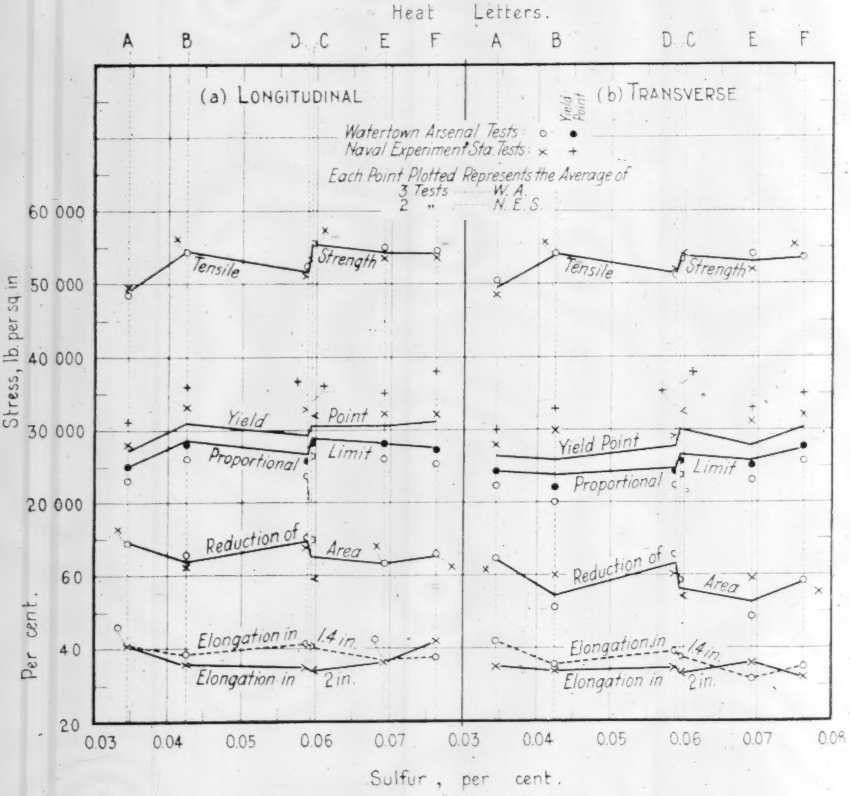

FIG. 8.—Tensile Properties of Universal Plates in Annealed Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

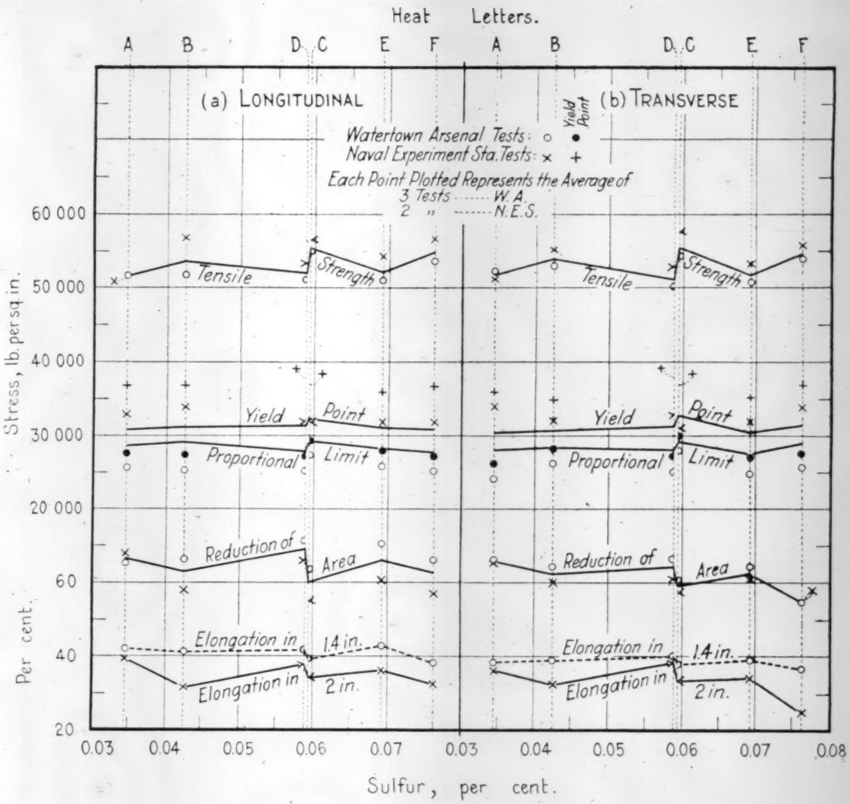

FIG. 9.—Tensile Properties of Sheared Plates in Annealed Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

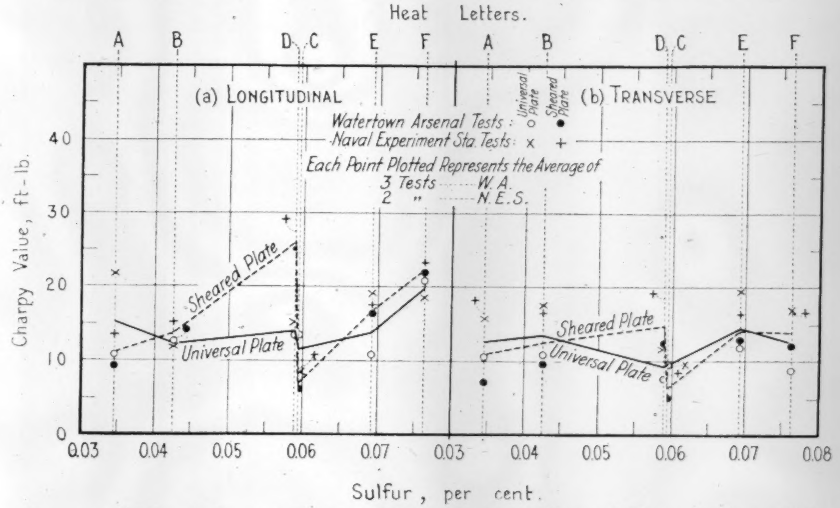

FIG. 10.—Charpy Impact Values of Universal and Sheared Plates in Annealed Condition.

(*a*) **Longitudinal: Axis of specimen parallel to long dimension of plate.**

(*b*) **Transverse: Axis of specimen perpendicular to long dimension of plate.**

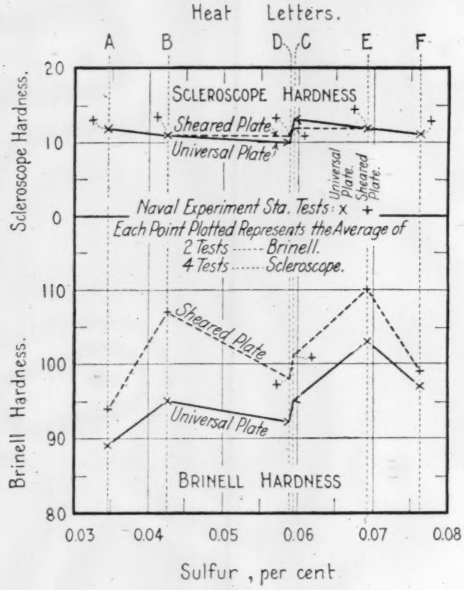

FIG. 11.—Brinell and Scleroscope Hardness Values of Universal and Sheared Plates in Annealed Condition.

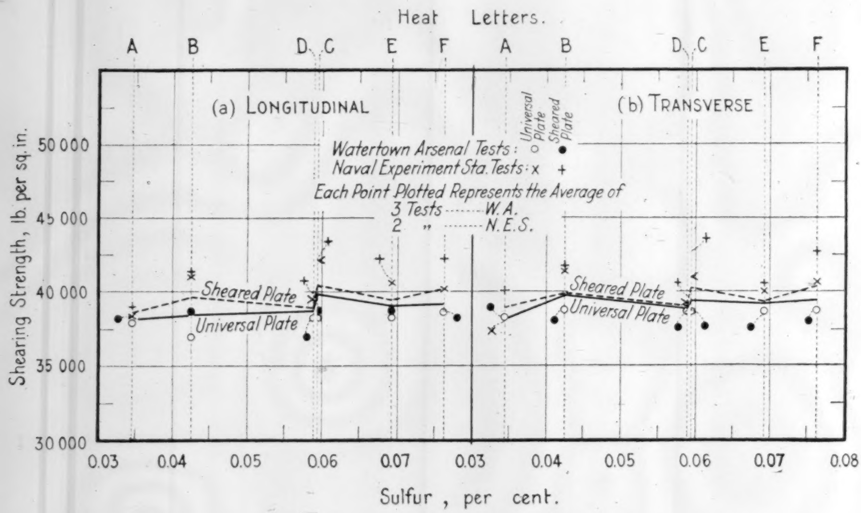

FIG. 12.—Shearing Properties of Universal and Sheared Plates in Annealed Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

the Naval Experiment Station are reported for comparison.) In Table I, the heats are arranged in the order of increasing average sulfur content as determined by the volumetric method.

The average percentages of carbon and manganese have been plotted against the average sulfur contents in Fig. 1. The phosphorus and silicon contents are quite low and are not plotted in the figure.

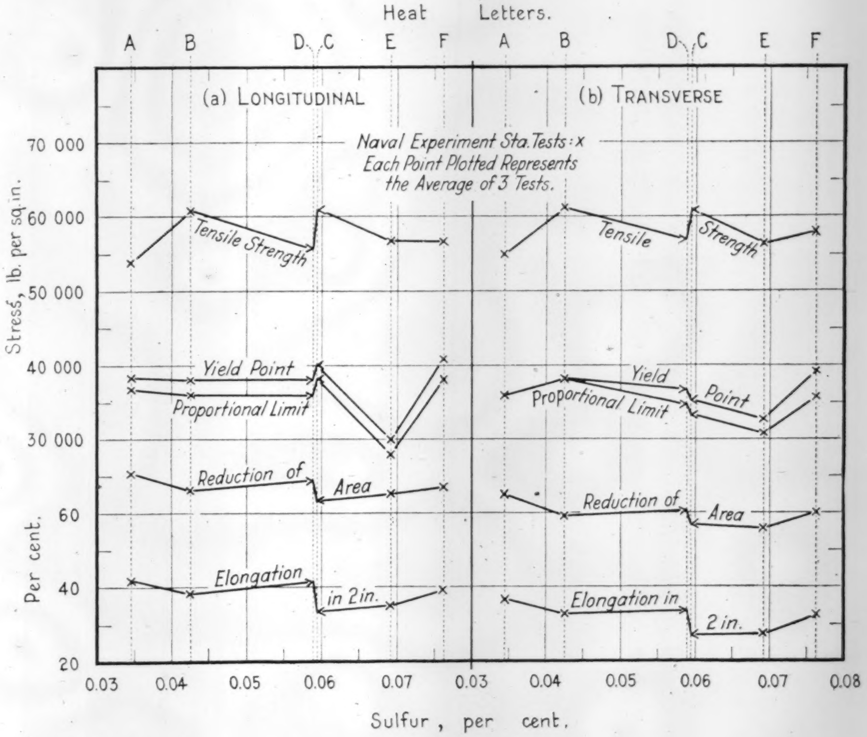

FIG. 13.—Tensile Properties of Universal Plates in Normalized Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

The average carbon content of the six heats is 0.205 per cent, the average deviation therefrom being 0.018 per cent and the maximum deviation 0.043 per cent. Attention is directed to the fact that heats *C* and *D*, having nearly identical sulfur contents, are widest apart in carbon content, having respectively 0.248 and 0.185 per cent carbon, which are the highest and lowest carbons of the six heats. The average manganese content of the six heats is 0.453 per

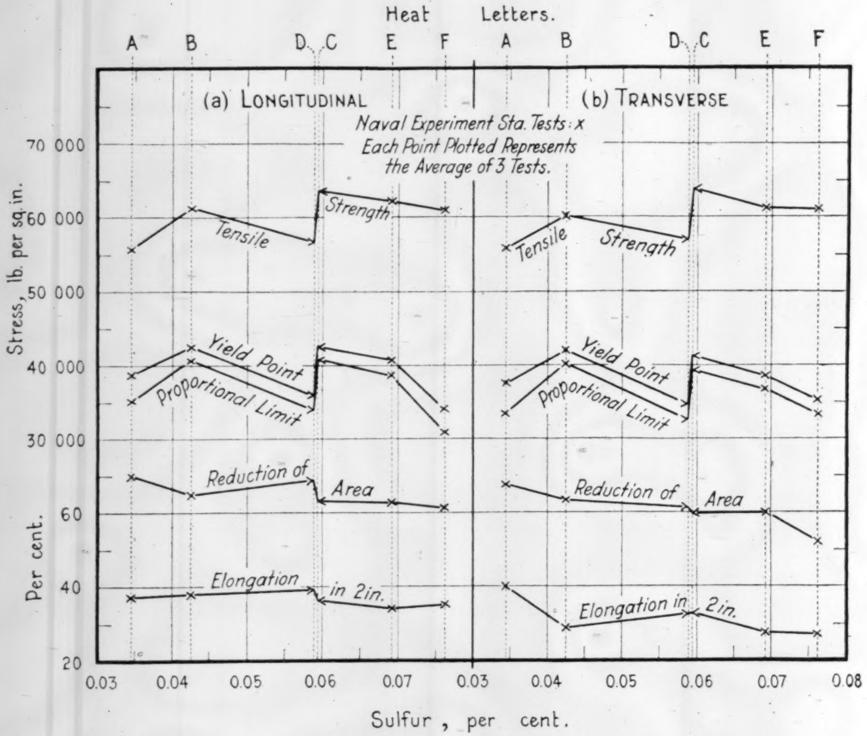

FIG. 14.—Tensile Properties of Sheared Plates in Normalized Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

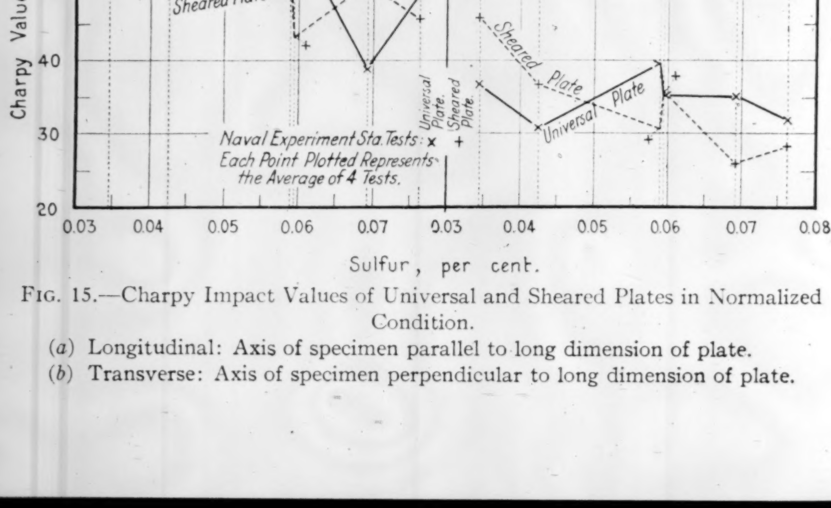

FIG. 15.—Charpy Impact Values of Universal and Sheared Plates in Normalized Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

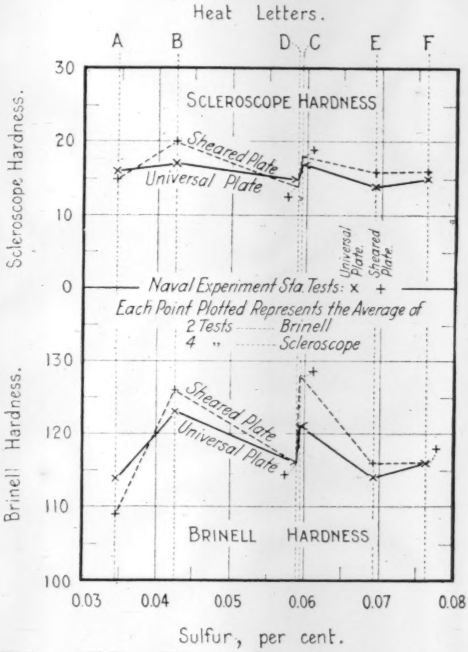

FIG. 16.—Brinell and Scleroscope Hardness Values of Universal and Sheared Plates in Normalized Condition.

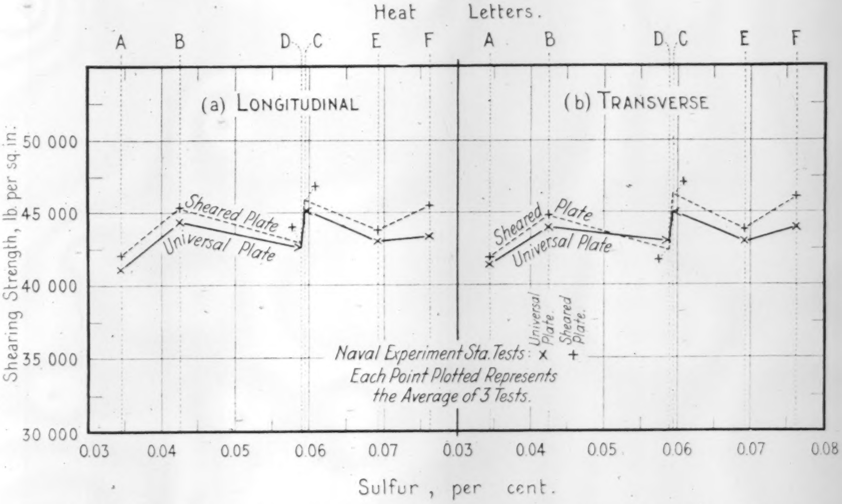

FIG. 17.—Shearing Properties of Universal and Sheared Plates in Normalized Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

cent, the average deviation therefrom being 0.024 per cent of manganese and the maximum deviation 0.045 per cent. It will be observed that heat *D*, having the lowest carbon, has next to the highest manganese content, 0.478 per cent, while heat *C*, having the highest carbon content, has next to the lowest manganese content, 0.433 per cent. It will also be observed from Fig. 1 that except for heats *C* and *D* the carbon contents are quite close to the average; whereas for manganese the higher sulfur heats are considerably higher in manganese than are the lower sulfur heats. Thus heat *A*, with lowest sulfur, has a manganese content of 0.408 per cent, whereas the high sulfur heat, *F*, has a manganese content of 0.484 per cent.

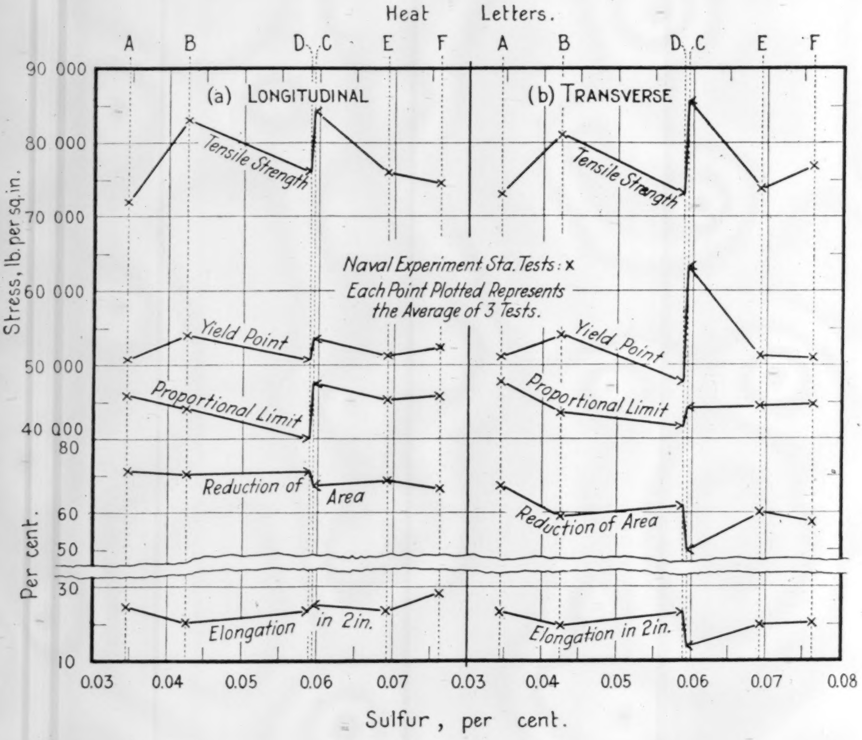

FIG. 18.—Tensile Properties of Universal Plates in Quenched Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

For the purpose of this preliminary report the committee presents the data on physical tests in graphical rather than tabular form, following the precedent of the previous reports. In the figures that follow, the percentages of sulfur are plotted as abscissas and the average properties determined are plotted as ordinates. Light vertical dotted lines are drawn at the average sulfur content for each heat (Table I) and are marked with the corresponding letters. The same vertical scales are used in the different figures wherever possible. An endeavor has been made in plotting the properties expressed in different units to use proportionate scales. The results obtained at the two laboratories are plotted separately. Straight lines have been drawn connecting the average of the values obtained at the two laboratories for successive heats, these averages being determined with regard to the number of tests of which each plotted value is the average.

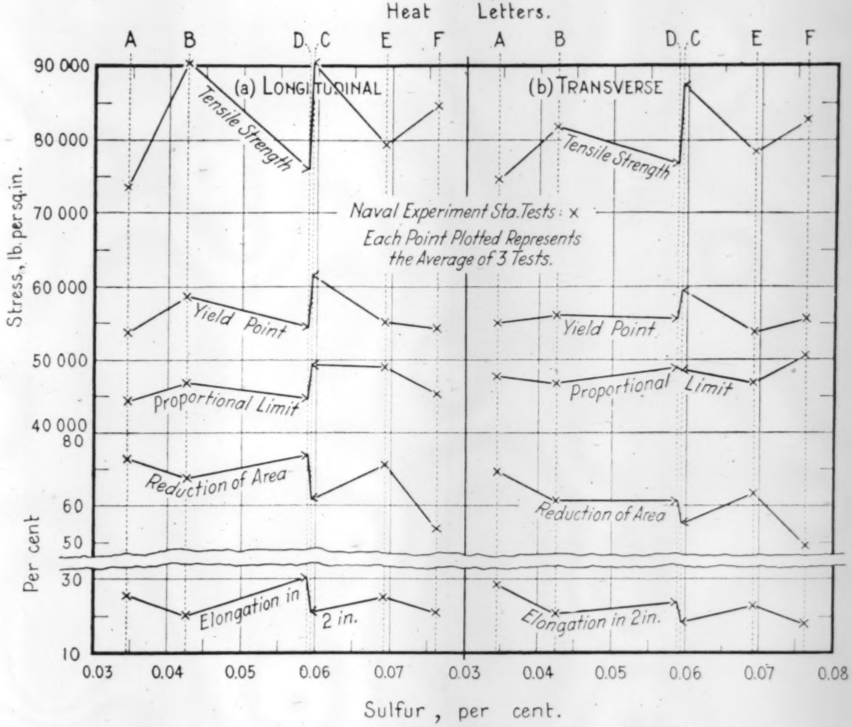

FIG. 19.—Tensile Properties of Sheared Plates in Quenched Condition.
(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.
(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

In Fig. 2 are shown typical stress-strain curves of tension specimens.

In Figs. 3 to 22, inclusive, are plotted the results of the tension, impact, hardness and shear tests on all material. The test data on universal and sheared plates are reported and plotted separately.

The results of tests of material in the natural condition will be found in Figs. 3 to 7, inclusive; in the annealed condition, in Figs. 8 to 12, inclusive; in the normalized condition, in Figs. 13 to 17, inclusive; and in the quenched condition, in Figs. 18 to 22, inclusive. In all cases the results of tests from the longitudinal and the transverse specimens are plotted side by side in one figure, thus facilitating a study of the influence of direction of test. In reporting the results of tension tests (Figs. 3, 4, 8, 9, 13, 14, 18 and 19), tensile strength, yield point, proportional limit, reduction of area and elongation in 2 and 1.4 in. are plotted. As stated earlier in the report, elongations were determined on a 2-in. gage length at the Naval Experiment Station and on a 1.4-in. gage length at Watertown Arsenal. The values for these elongations have not been averaged and separate curves have been drawn.

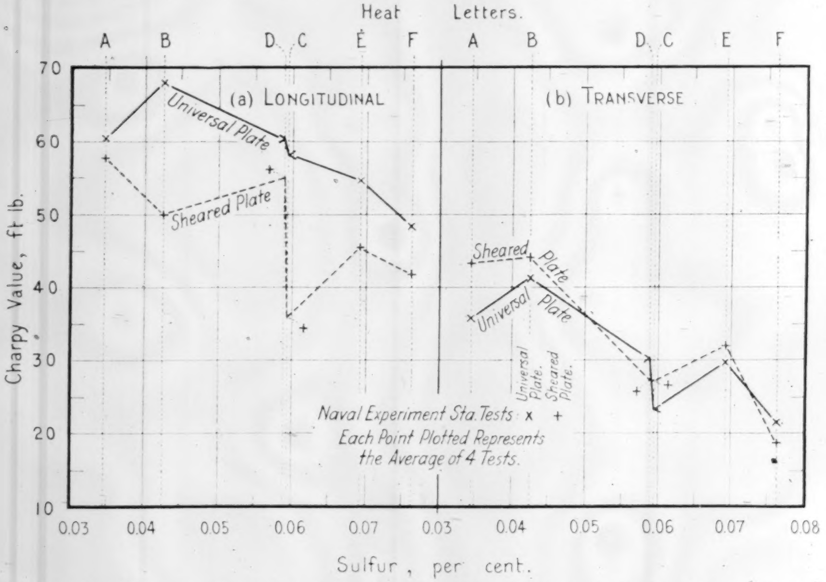

FIG. 20.—Charpy Impact Values of Universal and Sheared Plates in Quenched Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

Charpy impact values are reported in Figs. 5, 10, 15 and 20. The direction of impact for both longitudinal and transverse specimens was at right angles to the surface of the plate.

Brinell and scleroscope hardness values are reported in Figs. 6, 11, 16 and 21. The shear test values are reported in Figs. 7, 12, 17 and 22.

The results of the bend tests are given in detail in Table II.

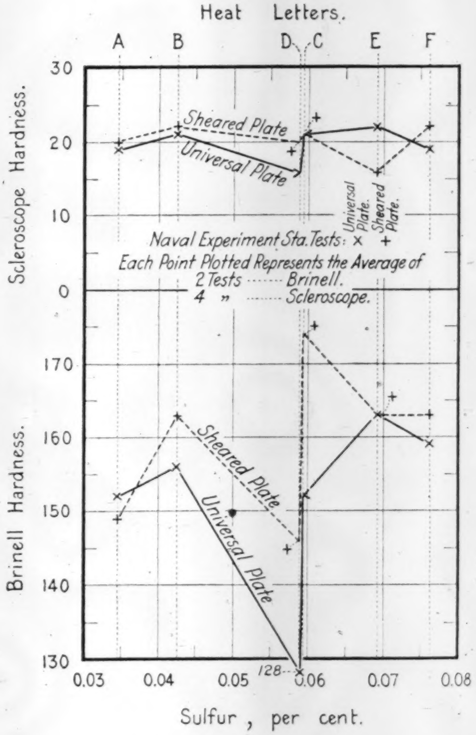

FIG. 21.—Brinell and Scleroscope Hardness Values of Universal and Sheared Plates in Quenched Condition.

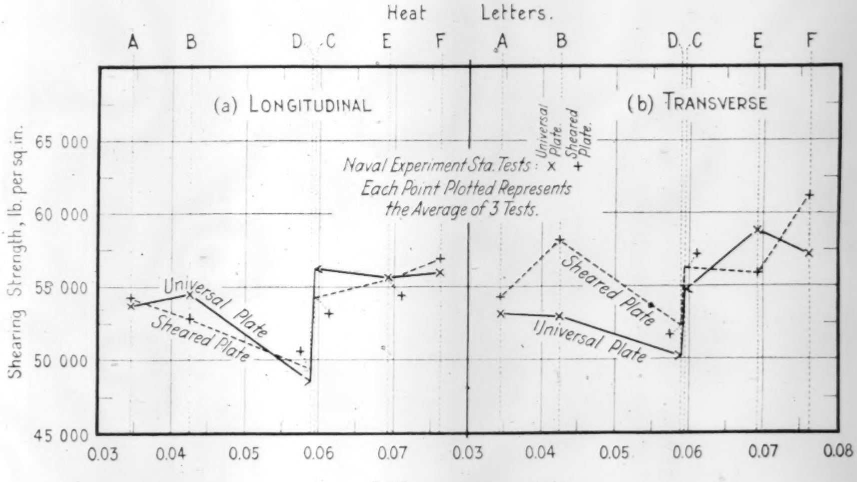

FIG. 22.—Shearing Properties of Universal and Sheared Plates in Quenched Condition.

(*a*) Longitudinal: Axis of specimen parallel to long dimension of plate.

(*b*) Transverse: Axis of specimen perpendicular to long dimension of plate.

TABLE II.—RESULTS OF BEND TESTS OF MATERIAL IN SERIES A, GROUP II.

Bend tests at Watertown Arsenal (designated W.A.) and at Naval Experiment Station (designated N.E.S.) were made on specimens machined to 1 by $\frac{1}{2}$ in. in cross-section with the corners rounded to a radius of $\frac{1}{16}$ in.

Material at W. A. tested in natural and annealed conditions. Material at N.E.S. tested in natural, annealed, normalized and quenched conditions.

All specimens were tested with the 1-in. face against the die block.

Material designated "longitudinal" was tested with the axis of the specimen parallel to long dimension of plate. Material designated "transverse" was tested with the axis of the specimen perpendicular to long dimension of plate.

O.K. = Specimen bent 180 deg. flat on itself without fracture.

Cr. = Specimen showed one or more small cracks at the angle designated.

Br. = Specimen showed one or more large cracks at the angle designated.

The numerals preceding these three designations are the number of specimens to which those designations apply. From these, the total number of tests for each heat in each condition is seen.

How Tested	Heat Letter	Heat Treatment					
		Natural		Annealed		Normalized	Quenched
		W. A.	N. E. S.	W. A.	N. E. S.	N. E. S.	N. E. S.
		UNIVERSAL PLATES					
Longitudinal	A	3 O.K.	2 O.K.	3 O.K.	1 O.K.	2 O.K.	2 O.K.
	B	"	"	"	"	"	1 O.K. 1 Br. 180°
	C	"	1 O.K. 1 Br. 180°	"	1 Br. 180°	"	1 O.K. 1 Br. 160°
	D	"	2 O.K.	"	1 O.K.	"	2 O.K.
	E	"	"	"	"	"	1 O.K. 1 Br. 48°
	F	"	"	"	"	"	2 O.K.
Transverse	A	3 O.K.	2 O.K.	3 O.K.	1 O.K.	2 O.K.	2 O.K.
	B	2 O.K. 1 Cr. 180°	2 Cr. 120, 170°	2 O.K. 1 Cr. 180°	1 Br. 180°	1 O.K. 1 Cr. 180°	2 Cr. 180°
	C	2 O.K. 1 Br. 100°	1 Cr. 120° 1 Br. 160°	2 O.K. 1 Cr. 180°	1 Br. 160°	1 O.K. 1 Cr. 180°	1 Cr. 125° 1 Br. 150°
	D	3 Cr. 180°	1 Cr. 180° 1 Br. 180°	3 O.K.	1 O.K.	1 O.K. 1 Cr. 180°	2 Br. 160, 175°
	E	3 Br. 120, 140, 140°	2 Cr. 180°	2 O.K. 1 Cr. 180°	1 Br. 180°	1 Cr. 180° 1 Br. 180°	1 Cr. 127° 1 Br. 47°
	F	1 O.K. 2 Br. 180°	1 O.K. 1 Cr. 180°	2 O.K. 1 Cr. 180°	"	2 O.K.	1 Cr. 140° 1 Br. 145°
		SHEARED PLATES					
Longitudinal	A	3 O.K.	2 O.K.	3 O.K.	1 O.K.	2 O.K.	2 O.K.
	B	"	"	"	"	"	1 O.K. 1 Cr. 175°
	C	1 O.K. 2 Cr. 180°	"	"	"	1 O.K. 1 Cr. 180°	2 O.K.
	D	3 O.K.	"	2 O.K. 1 Cr. 180°	"	2 O.K.	"
	E	"	"	3 O.K.	"	"	"
	F	"	"	"	"	"	1 O.K. 1 Br. 180°
Transverse	A	3 O.K.	2 O.K.	3 O.K.	1 O.K.	2 O.K.	2 O.K.
	B	"	1 Cr. 180° 1 Br. 180°	"	"	1 O.K. 1 Cr. 180°	1 O.K. 1 Cr. 180°
	C	1 O.K. 2 Cr. 180°	2 Br. 180°	1 O.K. 2 Cr. 180°	1 Cr. 180°	1 O.K. 1 Cr. 180°	2 Br. 180°
	D	1 O.K. 1 Cr. 180° 1 Br. 180°	1 Cr. 180° 1 Br. 180°	3 O.K.	"	2 O.K.	1 Cr. 170° 1 Br. 180°
	E	3 Cr. 180°	1 O.K. 1 Cr. 180°	1 O.K. 2 Cr. 180°	1 Br. 180°	1 O.K. 1 Cr. 180°	1 Cr. 145° 1 Br. 130°
	F	2 Cr. 180° 1 Br. 120°	2 Br. 180°	3 O.K.	"	1 Cr. 180° 1 Br. 180°	2 Br. 85, 125°

As has previously been stated, the Joint Committee, while it has reviewed all of the test data in this investigation, will defer any extended discussion of the results and the drawing and publishing of any conclusions therefrom. From the study of the data the Joint Committee has realized the possibilities that exist for study not only of the effect of sulfur upon these steels but the influence on physical properties of, for example, the various kinds of heat treatment used and the directions in which the specimens are taken. A comparative study of the data presented will be of value.

Metallographic study and a determination of the oxygen contents of these steels have been made and will be reported in the later complete publication.

Respectfully submitted on behalf of the Joint Committee,

GEORGE K. BURGESS,
Chairman.

C. L. WARWICK,
Secretary.

REPORT OF COMMITTEE A-2

ON

WROUGHT IRON

During the year Committee A-2 has held one meeting.

The tentative revisions recommended in 1922 in the Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 21) and in the Standard Specifications for Wrought-Iron Rolled and Forged Blooms and Forgings for Locomotives and Cars (A 73 – 18) and reprinted for convenience in the Appendix to this report are recommended for advancement to standard and in addition the committee asks for a nine-tenths vote on a revision of Section 9 of Specifications A 73 – 18, which revision also appears in the Appendix.

The committee also requests a nine-tenths vote on the revisions of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 21) described in detail in the Appendix. These revisions are recommended in order to adapt the specifications more closely to present practice.

In accordance with the request made several years ago for a specification for merchant bar iron which would recognize the largely used busheled scrap, the Tentative Specifications for Merchant Bar Iron (A 85 – 21 T)[1] were written, the physical properties required being the same as for refined wrought-iron bars. There having been no criticisms of these specifications received during the past three years, these specifications are recommended to the Society for advancement to standard.

The committee has been working with Committee A-1 on Steel on the Tentative Specifications for Lap-Welded and Seamless Steel Boiler Tubes and Lap-Welded Iron Boiler Tubes (A 83 – 22 T)[2] with a view to having one specification replacing the Standard Specifications for Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 21), the Standard Specifications for Lap-Welded and Seamless Steel and Wrought-Iron Boiler Tubes for Stationary Service (A 52 – 18) and the Standard Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives (A 38 – 21), and, pending favorable action of Committee A-1 on the revised Tentative Specifications A 83 – 22 T, asks for a nine-tenths vote on the recommendation to submit these revised tentative specifications to the Society for adoption as standard.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 474 (1921).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 553 (1922)

If unfavorable action is taken by Committee A-1 on Specifications A 83 – 22 T, the committee asks a nine-tenths vote for the revision of the "pressure formula" now appearing in Specifications A 38 – 21. This change is given in the Appendix.

The Tentative Specifications for Iron and Steel Chain (A 56 – 21 T)[1] have been the subject of extended study for several years, in order to make them conform to the best commercial practice. This study disclosed a lack of uniformity in some manufacturing details, particularly in the sizes and weights of links. All these differences are believed to be harmonized in the revised specifications appended hereto.[2] The designation of some of the classes are changed to those commercially in use, although the changes in the chain itself are only minor, principally in dimensions and weights. Three little-used sizes have been eliminated. The revised specifications are recommended for adoption as standard.

In accordance with the recommendation of Committee E-4 on Metallography, Committee A-2 has voted to accept the revised formula for etching solutions for all purposes in the specifications under the jurisdiction of the committee. These solutions are the following:

> "A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84) and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42) and 75 per cent water."

Following a demand for increased scope of Specifications A 72 – 21 for Wrought-Iron Pipe, the committee voted to add the Double-Extra-Strong Class to the specifications.

In view of the increasing prominence of oil country tubular goods it is thought desirable, in presenting the Specifications for Wrought-Iron Pipe (A 72 – 21) for adoption by the American Engineering Standards Committee, to clarify its scope by expanding Section 1 as given in the Appendix.

The results of the letter ballot on these recommendations are as follows:

Items	Affirmative	Negative	Not Voting
PROPOSED REVISION OF STANDARDS			
1. For Welded Wrought-Iron Pipe (A 72 – 21)	28	0	7
2. For Welded Wrought-Iron Rolled and Forged Blooms and Forgings for Locomotives and Cars (A 73 – 18)	28	0	7
3. For Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 21)	29	0	6
4. For Lap-Welded Charcoal-Iron Boiler Tubes (A 38 – 21)	30	0	5
TENTATIVE STANDARDS TO BE ADVANCED TO STANDARD			
5. For Merchant Bar Iron (A 85 – 22 T)	30	1	4
6. For Iron and Steel Chain (A 56 – 21 T) as revised	31	0	4
7. For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 22 T)	31	0	4

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 468 (1921).

[2] See 1924 Book of A.S.T.M. Standards.—ED.

The committee expects to take up during the coming year consideration of methods of chemical analysis of wrought iron as there has been some demand for standardization along this line.

This report has been submitted to letter ballot of the committee, which consists of 42 members, of whom 35 have voted affirmatively, none negatively, and 7 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. E. SMITH,
Chairman.

J. B. YOUNG,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Welded Wrought-Iron Pipe and for Welded Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars, proposed in 1922, amended as given in the appendix to this report, were approved and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars, proposed in 1924, as given in the appendix to this report, were approved at the annual meeting by nine-tenths vote and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The Standard Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives, a proposed revision of which is given in the appendix to this report, were superseded by the advancement to standard of the Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes, recommended by Committee A-1 and concurred in by Committee A-2. (See Editorial Note to Report of Committee A-1.) The specifications were accordingly withdrawn.

The Tentative Specifications for Iron and Steel Chain, revised as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The Tentative Specifications for Merchant Bar Iron were approved at the annual meeting, as recommended by the committee, and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications appear in the 1924 Book of A.S.T.M. Standards.

APPENDIX

REVISIONS OF STANDARDS AND TENTATIVE STANDARDS FOR WROUGHT IRON

1. Specifications for Welded Wrought-Iron Pipe (A 72–21):[1]

Section 1*:* Change to read as follows:

> "These specifications cover 'standard,' 'extra strong' and 'double extra strong' welded wrought-iron pipe."

Section 3 *(a)*.[2]—Change the words "puddled pig iron" to read "all pig puddled iron."

Tables I and II.[2]—Omit the words "Black and Galvanized" from under the titles of Tables I and II.

Table I.—Add a column at the right of Table I which shall give the test pressure for double extra strong pipe, making this table agree with Table I appearing on page 82.

Table II.—Add a column at the right of Table II giving the thickness and weight per linear foot for double extra strong pipe up to 8 in. in size, inclusive, making this table agree with Table II appearing on page 83.

2. Specifications for Welded Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73–18):[1]

Section 6 (a).[2]—Change the requirements given in the table included in Section 6 (*a*) from their present form: namely,

Tensile strength, lb. per sq. in.	45 000
Yield point, lb. per sq. in.	0.5 tens. str.
Elongation in 4 in., per cent	22
Reduction of area, per cent	30

to read as follows:

	Blooms	Forgings Classes A and B
Tensile strength, lb. per sq. in.	45 000	45 000
Yield point, lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 4 in., per cent	22	24
Reduction of area, per cent	30	33

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[1] 1921 Book of A.S.T.M. Standards.

[2] These revisions were recommended in 1922 and appear in the report of the committee for 1922. They are repeated here for convenience.

Section 9.—Change from its present form: namely,

"The number of tests and retests, if necessary, shall be agreed upon by the manufacturer and the purchaser."

to read as follows:

"Unless otherwise specified one test shall be made from each lot of 10 blooms or less and from each lot of 4000 lb. or less of forgings. These tests shall be made on prolongations the full size of the blooms or the largest section of the forging, and for test purposes, prolongations shall be furnished on at least 20 per cent of the blooms or forgings. In the case of small forgings, one forging may be used for test purposes, in which case one test will represent not more than 100 forgings."

3. SPECIFICATIONS FOR STAYBOLT, ENGINE-BOLT AND EXTRA-REFINED WROUGHT-IRON BARS (A 84 - 21).[1]—The following revisions are recommended:

Section 6 (*a*).—Add a paragraph permitting a minimum of 28 per cent elongation in 8 in. instead of 30 per cent for Grade A bars $\frac{7}{8}$ in. in diameter and smaller.

Section 8 (*c*).—Modify this section to include Grade A bars under the requirement for nick-bend tests.

Section 9.—Change to read as follows by the addition of the italicized words:

"The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material as follows:

"*Grade A*.—The material to have been rolled from a bloom, slab pile or box pile and to be *uniform and* free from steel.

"*Grades B and C*.—The material to be *uniform and* free from steel."

4. STANDARD SPECIFICATIONS FOR LAP-WELDED CHARCOAL-IRON BOILER TUBES FOR LOCOMOTIVES (A 38 - 21).[1]

Section 6.—In the formula for test pressure, change the term "*D*" to equal the outside diameter of tube in inches instead of the inside diameter of tube in inches.

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[1] 1921 Book of A.S.T.M. Standards.

DISCUSSION

PROPOSED REVISED SPECIFICATIONS FOR IRON AND STEEL CHAIN

Mr. Wiggin.

MR. T. H. WIGGIN.[1]—The speaker has had considerable experience, not all satisfactory, in purchasing chain and would like to have the committee's explanation on a few points before a vote is taken on the question of submitting these specifications to letter ballot for adoption as standard.

According to Section 2 of the specifications appended to the report of the committee,[2] Class A chain may contain re-worked scrap, which, according to a note to the section, is permitted to contain both iron and steel. This does not seem to cover chain made of stock resulting from piling alternate bars of steel and iron checkerboard fashion, according to the description of an important chain company. No class in the specifications seems to cover this product.

In Section 4 on chemical composition, no limits are given for phosphorus in wrought-iron chain though manganese is carefully specified. The speaker has had extraordinarily good chain with Mn 0.21 and P 0.15 per cent and execrable chain with Mn 0.10 and P 0.40 per cent. That too much phosphorus is detrimental is probably as well proven as most metallurgical conclusions. The U. S. Navy adheres to an upper limit of 0.10 per cent for phosphorus. That is doubtless unnecessarily severe for cheaper brands of chain but surely some limit to phosphorus should be named, say 0.12 per cent for Class AA chain and 0.16 per cent for Class A chain. Perhaps the committee believes that the pragmatical test of breaking a sample of chain will eliminate bad material. Then why not leave out manganese also? As a matter of fact, testing of sample pieces of chain is seldom practiced. It is particularly expensive in the case of auxiliary equipment such as shackles used with chain. The metal for shackles needs to be governed just as that in the chain.

A certain client of the speaker will probably never omit a test for phosphorus again. It was an open question in a large damage suit whether a certain technical legal defense could be successfully maintained in this enlightened age in the case of an accident caused by fracture of an article made of stock which had not been tested for phosphorus at the time of purchase. This article was found to have

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[1] Consulting Engineer, New York City.

[2] The specifications appear in the 1924 Book of A.S.T.M. Standards.—ED.

Mr. Wiggin. 0.45 per cent of phosphorus though procured from a reliable dealer. The omission of a limit for phosphorus in the chain specifications of the A.S.T.M. was counted on as a help in disproving negligence but this seems hardly reason enough for continuing the omission.

The speaker supposes the committee has good reasons for omitting phosphorus but before voting would be glad to hear what they are.

Mr. Smith. MR. H. E. SMITH[1] (*Chairman, Committee A-2*).—So far as such details are concerned, A.S.T.M. specifications naturally follow the general practice on the rolled bars, and no A.S.T.M. specifications for rolled bars include a phosphorus limit. During the past ten years, wrought iron has been analyzed more than previously, and it is possible that phosphorus and perhaps some other details are the coming thing in iron analysis. Thus far no generally recognized standards have been worked up; they are really in advance of the present commercial condition.

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[1] Engineer of Tests, New York Central Lines, New York City.

REPORT OF COMMITTEE A-3
ON
CAST IRON

Committee A-3 on Cast Iron has developed considerable activity during the past year. The Tentative Specifications for High-Test Gray-Iron Castings (A 88 – 22 T),[1] for Chilled Cast-Iron Wheels (A 46 – 22 T),[2] and for Foundry Pig Iron (A 43 – 22 T)[3] are now ready for advancement to standard, and it is recommended by the committee that they be so advanced, the latter two specifications being revised as follows:

Tentative Specifications for Chilled Cast-Iron Wheels.—

Section 2.—Change the last item to read as follows:

Sulfur, maximum, per cent.......	0.17 for 1923 to 1924, incl. 0.16 " 1925 to 1926, " 0.15 " 1927 to 1928, " 0.14 " 1929 and thereafter.

Section 9.—Change to read as follows:

"The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works."

Tentative Specifications for Foundry Pig Iron.—

Section 2.—Change to read as follows:

"(*a*) The pig iron shall conform to the chemical requirements specified by the purchaser at the time of purchase, with the following permissible variations from the specified percentage in the case of pig iron intended for the manufacture of gray-iron castings.

Silicon................	0.25 per cent and below
Manganese............	0.30 " " " "
Phosphorus............	0.15 " " " "
Sulfur..................	not over specified percentage.
Total Carbon..........	not less than specified percentage.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 575 (1922).

[2] *Ibid.*, p. 569.

[3] *Ibid.*, p. 566.

"(*b*) In the case of pig iron for making steel and malleable iron castings, a maximum percentage of phosphorus and either a maximum or minimum percentage of manganese may be specified."

To the appendix, which is a recommendation and not a part of the specifications, add the following to the code symbols:

SILICON	TOTAL CARBON	PHOSPHORUS
3.75 per cent Ld	4.00 per cent Cy	1.75 per cent Pd
4.00 " " Lf		2.00 " " Pf

Progress has been made in the matter of recommended practice for the composition of specific lines of castings, discussed in the committee's report last year, the conclusion being delayed by the regrettable death of the Chairman of the Sub-Committee on General Castings, Mr. H. E. Diller, to whose memory high tribute is paid. The committee has the continuance of the work under consideration and expects to report upon it next year.

The active cooperation of the U. S. Bureau of Standards has been enlisted for joint work on the now desirable revision of the Standard Methods of Sampling and Analysis of Pig and Cast Iron (A 64 – 16).[1] Progress will be reported upon this in due season.

The committee has been greatly strengthened during the year as to personnel in the consideration of revised specifications for cast-iron pipe. The pipe industry is experiencing considerable development of late, and a general standardization is in order. The introduction of centrifugally-cast iron pipe in metal and other molds necessitates special provision for proper testing of the product. Special provision has been made on the program of one of the sessions of the Society to afford discussion of the subject of cast-iron pipe in general. The American Engineering Standards Committee sponsored a general conference on the subject of standards for cast-iron pipe, held June 5, for the purpose of correlating the interests of such bodies as the American Water Works Association, New England Water Works Association, American Gas Association, the A.S.T.M., and the manufacturers, and, if possible, adopting a generally acceptable program for development of standards. As a result of this conference, the American Water Works Association, the American Gas Association and the American Society for Testing Materials have been invited by the Standards Committee to undertake the work of developing such standards through the organization of a Sectional Committee on Standards for Cast-Iron Pipe under their joint sponsorship and with the cooperation of all interested groups.

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[1] 1921 Book of A.S.T.M. Standards.

In connection with the international meeting of foundrymen in Paris, last September, the chairman of the committee, at the invitation of the French hosts, presented a report on the subject of testing cast iron, and also delivered addresses before the foundrymen of Sheffield and Manchester in England. With the vice-chairman of the committee, conferences were held with the British and French committees on testing cast iron in conjunction with the president of the American Foundrymen's Association, as part of the program of the visiting American foundrymen at the Paris meeting. The result of this work has been the formation of an International Committee on the subject, with the purpose of reconciling the viewpoints of British, French, and American engineers and foundrymen. The British desire three standard test bars of small, medium and large diameters to represent castings of the corresponding three classes; the French wish to take small rods from the castings themselves, for a shearing test to judge the value of the material; and the Americans prefer one standard bar of medium diameter, but with three different strength values to represent the metal going into light, medium and heavy castings.

Research work on this problem is now going on in the three countries in question, with the understanding that the foundrymen and engineers of Belgium, Spain, Italy, Czechoslovakia and Poland are also at work. The object is to provide means of testing cast-iron products for export only, and no interference with the customs of the industry in the several countries is urged or contemplated. This development, brought about last fall under the auspices of the American Foundrymen's Association, is the continuation of the original work done by the same members of Committee A-3 under the auspices of the former International Association for Testing Materials, the activity of which was ended by the World War. It is to be hoped that tangible results may accrue from this renewal of effort to benefit international trade.

The vice-chairman of the committee at the same time undertook to revive the matter of International Specifications for Pig Iron for Export, picking up the lines of this work where halted by the war. He had a number of conferences with the British National Federation of Iron and Steel Manufacturers, and the French Comité des Forges on the subject. The result is that the American proposals, which are the A.S.T.M. Specifications, have the benevolent interest of the British iron-masters with almost "tentative" acceptance, and the French iron-masters have come back with a substitute proposal giving somewhat wider composition limits. The subject is, therefore, well under way, and should lead to an eventual satisfactory understanding.

This report has been submitted to letter ballot of the committee, which consists of 66 members, of whom 38 have voted affirmatively, one negatively, and 27 have refrained from voting.

Respectfully submitted on behalf of the committee,

RICHARD MOLDENKE,
Chairman.

G. C. DAVIES,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Foundry Pig Iron, proposed as tentative in 1922, amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Specifications for Chilled Cast-Iron Wheels, revised as recommended in this report, were approved and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The Tentative Specifications for High-Test Gray-Iron Castings, referred to in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications appear in the 1924 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE A-4
ON
HEAT TREATMENT OF IRON AND STEEL

Committee A-4 on Heat Treatment of Iron and Steel has held three meetings during the past year as follows: At Atlantic City on June 25, 1923; at Pittsburgh on October 12, 1923; and at Pittsburgh on March 14, 1924. Ten new members were elected during the year.

E. W. Ehn has accepted the chairmanship of Sub-Committee IV on Case Hardening and Heat Treatment of Case-Hardened Objects.

A. V. de Forest has been made chairman of Sub-Committee V on Heat Treatment of Wrought Iron.

New sub-committees on Heat Treatment of Gray Cast Iron and Heat Treatment of Malleable Cast Iron have been formed.

Sub-Committee I on Heat Treatment of Rolled and Forged Carbon Steel has adopted the following slight changes in the Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects (A 35 – 21):[1]

1. *Section 2* on "Method of Heating."—Change the first sentence to read as follows by the omission of the words in brackets:

> "In the case of large objects, the heating of the interior of which lags behind that of the outside, [though the early part of the heating may if desired be rapid,] the final approach to the annealing temperature aimed at should be slow, so that the interior may be brought fully up to it without carrying the exterior far beyond it, because in general any needlessly high temperature is injurious, and tends to re-coarsen the grain."

2. *Section 14* on "Special Annealing to Remove the Effects of Rolling, etc."—Change the last sentence of the second paragraph to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "[Great brittleness] *large grain size* may be caused by annealing very low carbon steel in the neighborhood of 700° C. (1292° F.) after cold working."

Committee A-4 has approved these revisions and recommends that they be referred to letter ballot of the Society for adoption this year.

The recommended practice of the American Society for Steel Treating for the Heat Treatment of Plain Carbon Tool Steel has been under consideration for the reason that Committee A-1 on Steel has voted to append this recommended practice to its specifications for carbon tool steel, and seeks the advice of Committee A-4. This recommended practice of the A.S.S.T. is a tentative one and in view of possible revisions it is planned to have Sub-Committee I review the recommended practice and forward any suggested changes to the American Society for Steel Treating, with the object of enabling them to produce a practice acceptable to both societies.

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[1] 1921 Book of A.S.T.M. Standards.

Sub-Committee II on Heat Treatment of Iron and Steel Castings.—This sub-committee has considered during the year the Tentative Recommended Practice for Heat Treatment of Carbon-Steel Castings (A 36 – 22 T)[1] submitted in 1922 and continued as tentative last year. As a result the Recommended Practice has been extensively revised and rearranged so that the procedures for annealing, normalizing, normalizing followed by reheating, and quenching followed by reheating, are specifically covered. This revised recommended practice is appended hereto[2] and the committee recommends that it be referred to letter ballot of the Society for approval to supersede the present Recommended Practice for Annealing of Carbon-Steel Castings (A 36 – 14).[3]

Sub-Committee III on Heat Treatment of Alloy Steels is reviewing a recommended practice of the American Society for Steel Treating for the Heat Treatment of 18-per-cent Tungsten High-Speed Steel, which has been referred to the committee under the same circumstances as previously mentioned in discussing the activities of Sub-Committee I.

Sub-Committee IV on Case Hardening and Heat Treatment of Case-Hardened Objects is preparing an extensive revision of the present Recommended Practice for Heat Treatment of Case-Hardened Carbon-Steel Objects (A 37 – 14), which it is expected will be ready for presentation at the June meeting of the committee.

Sub-Committee V on Heat Treatment of Wrought Iron has submitted a report of progress, but states that it has been very difficult to decide upon the proper tests to conduct to fit the particular problems confronting the sub-committee.

Sub-Committee VI on Nomenclature and Definitions.—Committee A-4 reported last year the appointment of R. M. Bird as special representative on a joint committee, consisting of representatives of the American Society for Testing Materials, American Society for Steel Treating, and the Society of Automotive Engineers, for the consideration of uniform definitions of terms relating to heat treatment. This joint committee has not as yet reached an agreement on definitions of these terms. A committee of the American Society for Steel Treating has prepared definitions of certain terms, which have been submitted by the A.S.S.T. to a number of other technical societies for their consideration and comment. The Executive Committee of our Society has referred these definitions to Committee A-4 and Sub-Committee VI has been requested to review them and report their comments to the main committee.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 643 (1922).

[2] See 1924 Book of A.S.T.M. Standards.—ED.

[3] 1921 Book of A.S.T.M. Standards.

This report has been submitted to the letter ballot of the committee, which consists of 41 members, of whom 32 have voted affirmatively, none negatively, and 9 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. M. BOYLSTON,
Chairman.

J. H. HALL,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects, proposed in 1924, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The recommended practice, as revised, appears in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Recommended Practice for Annealing of Carbon-Steel Castings, submitted in 1922 and amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The recommended practice, as revised, appears in the 1924 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE A-5
ON
CORROSION OF IRON AND STEEL

The report of Committee A-5 consists mainly of the reports of its sub-committees, all of which have been active and have made substantial progress in the work during the past year.

Sub-Committee III on Inspection of the Fort Sheridan, Pittsburgh, and Annapolis Tests reports additional failures at Fort Sheridan among the non-copper-bearing groups of sheets, with no failures in any of the copper-bearing groups. The first failures at Annapolis were recorded at the October, 1923, inspection, the sheets failing first being in the same non-copper bearing groups failing first at Pittsburgh and at Fort Sheridan.

Sub-Committee V on Total Immersion Tests reports failure of all of the light-gage sheets at the Washington location, and about 60 per cent of the light-gage sheets at Annapolis. A table giving a comparison of the failures in the light-gage sheets in the Calumet Mine test completed in 1921, and the corresponding groups of sheets in the Washington tests shows the average life of the sheets immersed in water from the City of Washington supply to be about $18\frac{1}{2}$ times longer than the corresponding sheets immersed in mine water. The tests thus far do not indicate any outstanding superiority for any one type of metal, and the presence of copper added to the various types of metal does not increase its resistance to corrosion, when the samples are totally and continually submerged in running water of acid or alkaline reaction.

Sub-Committee VI on Specifications for Galvanized Sheets presents specifications for hot-dipped galvanized sheets. Committee A-5 recommends their acceptance for publication as tentative.

Sub-Committee VII on Accelerated Tests has made definite progress during the year and reports the completion of a program for the investigation of a number of proposed methods, some of which are described in detail by H. S. Rawdon, A. I. Krynitsky, and W. H. Finkeldey, in a paper presented at this meeting.[1] The work of this sub-committee will parallel the field exposure tests now being arranged by Sub-Committee VIII on Tests of Metallic Coatings.

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[1] H. S. Rawdon, A. I. Krynitsky and W. H. Finkeldey, "Types of Apparatus Used in Testing the Corrodibility of Metals," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

Sub-Committee VIII on Tests of Metallic Coatings reports plans for conducting comprehensive exposure tests on metallic products coated by eight recognized commercial processes, the tests to be located at four different points representing as many varying conditions. The importance of developing reliable service information on the value of the various metallic coatings is very apparent to all concerned, and the work of this sub-committee should have the most hearty cooperation of the producers of these products. In view of the comprehensive tests being conducted by the U. S. Bureau of Standards on soil corrosion, the committee does not believe it desirable to undertake any soil corrosion tests at the present time.

The Tentative Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 - 23 T)[1] and the Tentative Methods of Determining Weight of Coating on Tin, Terne and Lead-Coated Sheets (A 91 - 23 T)[2] accepted for publication at the last annual meeting have been very favorably received, and it is now recommended that they be advanced without change to standard.

At the invitation of the American Engineering Standards Committee, members of Committee A-5 represented the Society at a conference held in January to consider the question of nationally uniform specifications for various classes of zinc-coated materials. This conference, attended by a large number of interested organizations, resolved to undertake the preparation of specifications for the adequate protective coating of different classes of zinc-coated products. It was the general feeling of the conference that the scope of work was larger than contemplated by any organization now at work, and that the best results would be accomplished by organizing the work under a sectional committee including all interests, and that the Society in view of its present active interest in the subject might serve acceptably in organizing this sectional committee to sponsor this important work.

The committee records with profound sorrow the death of its Secretary, Mr. Daniel M. Buck, which occurred suddenly at Vandergrift, Pa., in January. Mr. Buck had been a valuable member of the committee for a number of years, and had given unsparingly of his time and energy in developing its work. For a number of years Mr. Buck had been actively engaged in research work relating to corrosion problems, and his contributions on the subject had given him a prominent place in the field of ferrous metallurgy. Probably his most notable work was done in connection with the production of copper steel, his interest in the product doing much to stimulate the more recent researches of the committee, which have given valuable data on the corrosion resistance of a wide variety of steel and iron products. We shall miss his genial companionship, his generous helpfulness, and his impartial and straightforward judgment in the councils of the committee, and yet the inspiration of his association will always remain as a wholesome incentive for greater accomplishments.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 566 (1923).

[2] *Ibid.*, p. 573.

This report has been submitted to letter ballot of the committee, which consists of 49 members, of whom 35 have voted affirmatively, none negatively, and 14 have refrained from voting.

Respectfully submitted on behalf of the committee,

J. H. GIBBONEY,
Chairman.

JAMES ASTON,
Temporary Secretary.

EDITORIAL NOTE

The Tentative Methods of Determining Weight of Coating on Zinc-Coated Articles and the Tentative Methods of Determining Weight of Coating on Tin, Terne and Lead-Coated Sheets, referred to in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods appear in the 1924 Book of A.S.T.M. Standards.

The proposed Tentative Specifications for Hot-Dipped Galvanized Sheets, referred to in this report, were accepted for publication as tentative and appear on page 775.

REPORT OF SUB-COMMITTEE III ON INSPECTION OF THE FORT SHERIDAN, PITTSBURGH, AND ANNAPOLIS TESTS

Sub-Committee III on Inspection has held three meetings during the past year.

FIRST MEETING

The first meeting was held at Annapolis, Md., on October 10, 1923, with Messrs. Aupperle, Buck, Fleming, McDonnell, Smith and Thompson present—Messrs. Cooper, Gibboney, and the representative of the Quartermaster's Corps of the U. S. War Department being absent.

The Annapolis sheets were inspected on October 10, 1923, followed by the inspection of the Fort Sheridan sheets on October 12, 1923, Mr. McDonnell leaving the sub-committee at Annapolis, and Mr. Llewelyn substituting for Mr. Thompson at Fort Sheridan.

The first failures were found at Annapolis at this inspection, representing an exposure period of 84 months, and were as follows:

Sheet O-1 (No. 22 Gage Low-Copper Open-Hearth Steel, Series A), failed due to small hole and ragged edge at bottom of sheet.

Sheet S-5 (No. 22 Gage Low-Copper Pure Iron, Series B), manufactured by the American Rolling Mill Co. This sheet failed due to a small hole near the lower end.

The following sheets were noted as having received mechanical damage: namely, H-4, K-12, S-4, S-6, U-1, and Y-2.

No photographic record was made of the failed sheets at Annapolis.

While the rate of corrosion at Annapolis has been decidedly slower than at the Pittsburgh and Fort Sheridan locations, it will be observed that the sheets failing first at the Annapolis location belong to the same groups of low-copper open-hearth steel, and low-copper pure iron that failed first in the Pittsburgh and Fort Sheridan tests, which development indicates that the three different atmospheric conditions show the same general tendencies, only with varying rates of corrosion.

The following failures were found at Fort Sheridan at this inspection:

Sheet A-25 (No. 22 Gage Bessemer Steel, Series A), failed due to small hole in lower end.

Sheet Y-6 (No. 22 Gage Low-Copper Wrought Iron, Series B), manufactured by the Youngstown Sheet and Tube Co., failed due to hole near lower end.

Sheet C-29 was recorded as showing a mechanical injury, small hole at bottom of dent.

No photographic record was made of the failed sheets at Fort Sheridan.

SECOND MEETING

The second meeting was held at Fort Sheridan, Ill., April 16, 1924, with Messrs. Aupperle, Fleming, McDonnell and Smith present—Messrs. Cooper, Gibboney and representatives of the Bureau of Steam Engineering of the U. S. Navy Department, and the Quartermaster's Corps of the U. S. War Department being absent.

The Fort Sheridan sheets were inspected on April 16, 1924, followed by the inspection of the Annapolis sheets. Messrs. Gibboney and the representative of the Bureau of Steam Engineering of the U. S. Navy Department joined the sub-committee at Annapolis, Mr. McDonnell leaving the sub-committee at Fort Sheridan, not making the Annapolis inspection.

The following additional failure was noted at Fort Sheridan at this inspection:

Sheet A-21 (No. 22 Gage Bessemer Steel, Series A), failed due to hole in lower end. No photographic record was made of this failure.

The Annapolis sheets were inspected on April 18, 1924, and no additional failures were found.

The sub-committee at its inspections of October, 1923, and April, 1924, observed that the condition of the surfaces of the sheets, as regarding texture, color and adherence of rust, show substantially the same general characteristics as recorded at preceding inspections, and for this reason detailed data in the form of condensed statements of numeral ratings are not made a part of this report.

Table I, Plate I, is presented as a continuation of the same general plan of grouping all sheets at the Fort Sheridan location as regarding the presence of copper, and recording the failures at all inspection periods. It will be noted that all of the sheets in four groups of low-copper bessemer and open-hearth steel and pure iron have failed, and that of the total No. 22 gage non-copper-bearing sheets, 50 per cent have failed, whereas none of the copper-bearing sheets have failed.

Table II, Plate II, is presented as showing all sheets at the Annapolis location grouped as regarding the presence of copper, into

TABLE I.—FAILURES AT FORT SHERIDAN TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920, 1921, 1922, 1923 AND APRIL

Group	Designation	Series	Description	Average Analysis						Number of Sheets in Test	
				Carbon	Man-ganese	Phos-phorus	Sulfur	Silicon	Copper		Mar. 31 24 Mo
											No. 16 Ga
EE	Puddled Iron	A	Copper-Bearing	0.035	0.03	0.119	0.018	0.125	0.319	12	No
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237	17	No
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247	19	No
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234	19	No
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236	12	No
TT	Copper-Bearing Steel, Newport Rolling Mill Co	B	" "	0.080	0.313	0.009	0.020	0.006	0.223	14	No
UU	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.018	0.066	0.008	0.028	0.005	0.239	13	No
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.018	0.046	0.007	0.019	0.004	0.299	19	No
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.08	0.40	0.091	0.035	0.006	0.154	1	No
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.08	0.34	0.094	0.037	.....	0.279	2	No
ZZ	Copper-Bearing Bessemer Steel Youngstown Sheet and Tube Co	B	" "	0.07	0.36	0.082	0.033	.....	0.528	2	No
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.37	0.050	0.052	.....	0.172	2	No
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.09	0.34	0.038	0.077	0.003	0.641	2	No
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.39	0.049	0.044	.....	0.318	2	No
	Total	....	....	.....	.....	.....	.....	.....	.....	136	No
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.419	0.083	0.042	0.004	0.012	17	No
BB	Open-hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.129	17	No
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067	12	No
DD	Low-Copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028	19	No
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029	12	No
MM	Open-hearth Steel, Alan Wood Iron and Steel Co	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057	14	No
SS	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025	12	No
XX	Low-Copper Pure Iron, Inland Steel Co	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028	14	No
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023	3	No
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.08	0.45	0.102	0.037	0.008	0.014	2	No
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.022	0.39	0.040	0.028	.....	0.030	2	No
	Total	....	....	.....	.....	.....	.....	.....	.....	124	No
											No. 22 Ga
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27	0.014	0.053	0.006	0.156	2	No
C	Copper-Bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.195	10	No
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283	12	No
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244	11	No
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.365	0.097	0.068	0.008	0.252	19	No
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237	16	No
M	Open-hearth Steel, Alan Wood Iron and Steel Co	B	" "	0.093	0.419	0.013	0.041	0.011	0.185	14	No
T	Copper-Bearing Steel, Newport Rolling Mill Co	B	" "	0.083	0.313	0.009	0.020	0.005	0.227	14	No
U	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.017	0.074	0.008	0.037	0.005	0.260	14	No
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.018	0.051	0.007	0.021	0.005	0.304	14	No
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.37	0.094	0.038	0.007	0.263	2	No
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.05	0.37	0.114	0.048	.....	0.533	2	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.35	0.049	0.059	.....	0.212	2	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.39	0.047	0.047	.....	0.286	2	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.07	0.41	0.042	0.042	.....	0.532	2	No
	Total	....	....	.....	.....	.....	.....	.....	.....	136	No
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.386	0.089	0.040	0.007	0.014	15	No
B	Open-hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.103	11	No
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.144	2	No
D	Low-Copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024	6	No
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.536	0.008	0.030	0.249	0.020	12	No
S	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.02	0.023	0.006	0.022	0.004	0.022	14	No
X	Low-Copper Pure Iron, Inland Steel Co	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027	14	No
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020	3	No
Z	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.07	0.44	0.107	0.046	0.003	0.011	2	No
Z	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.06	0.38	0.077	0.035	0.009	0.130	2	No
Z	Open-hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.06	0.32	0.065	0.044	0.002	0.018	2	No
	Total	....	....	.....	.....	.....	.....	.....	.....	83	No

[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent copper as copper-bearing.

[2] No failures were recorded at inspections made prior to March 31, 1919; the detail records are accordingly not given here.

PLATE I.
PROC. AM. SOC. TESTING MATS.
VOL. 24, PART I.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

APRIL, 1924. SHEETS EXPOSED APRIL 9, 1917. COMPARING COPPER-BEARING WITH NON-COPPER-BEARING MATERIALS.[1]

Date of Inspection											Number of Sheets Failed in Test
Mar. 31, 1919.[a] 24 Months	Dec. 6, 1919. 32 Months	May 10, 1920. 37 Months	Oct. 11, 1920. 42 Months	Apr. 4, 1921. 48 Months	Oct. 17, 1921. 54 Months	Apr. 10, 1922. 60 Months	Oct. 16, 1922. 66 Months	Mar. 8, 1923. 71 Months	Oct. 12, 1923. 78 Months	Apr. 16, 1924. 84 Months	
16 GAGE SHEETS											
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	13 (1)	None	None	None	None	None	1
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	1	None	None	None	None	None	1
22 GAGE SHEETS											
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	16, 17, 18 (3)	None	19, 29, 30, (3)	None	None	22 (1)	None	25 (1)	21 (1)	9
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	22 (1)	None	None	None	1
None	14, 15, 21 (3)	13, 16, 19, 23, 24 (5)	17, 18, 20, 22 (4)	....	....	....	....	....	....	....	12 (All)
None	None	None	None	None	16, 22, 25, 26, 28 (5)	17, 18, 19, 20, 21 23, 24, 27 (8)	15 (1)	....	....	....	14 (All)
None	None	None	None	25 (1)	None	None	15, 17 (2)	None	None	None	3
None	None	None	4 (1)	None	None	None	None	None	6 (1)	None	2
None	None	None	None	4, 5 (2)	....	....	....	....	....	....	2 (All)
None	None	None	None	None	None	None	None	None	None	None	None
None	None	421 (1)	None	None	420 (1)	....	....	....	....	....	2 (All)
None	3	9	5	6	6	8	5	0	2	1	45

TABLE II.—FAILURES AT ANNAPOLIS TESTS. INSPECTIONS OF 1917, 1918, 1919,
COMPARING COPPER-BEARING WITH NO

Group	Designation	Series	Description	Carbon	Ma gane
				No. 16 GAGE S	
EE	Puddled Iron	A	Copper-Bearing	0.035	0.0
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.3
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.3
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.4
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.0
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.080	0.3
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.018	0.0
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.0
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.113	0.4
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.080	0.3
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.073	0.3
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.074	0.3
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.077	0.3
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.4
	Total	......	......	.....	...
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.4
BB	Open-hearth Steel	A	" " "	0.056	0.3
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.0
DD	Low-Copper Pure Iron	A	" " "	0.019	0.0
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.3
MM	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.017	0.4
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.017	0.0
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.0
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.0
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.08	0.4
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.047	0.3
	Total	......	......	.....	...
				No. 22 GAGE SHE	
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27
C	Copper-Bearing Pure Iron	A	" "	0.015	0.02
E	Puddled Iron	A	" "	0.033	0.03
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.38
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.36
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.44
M	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.093	0.41
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.083	0.31
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.07
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.05
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.058	0.37
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.055	0.38
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.067	0.35
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.35
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.073	0.42
	Total	......	......	.....	...
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.38
B	Open-hearth Steel	A	" " "	0.09	0.38
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.02
D	Low-Copper Pure Iron	A	" " "	0.02	0.02
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.53
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.02	0.02
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.05
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.05
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.063	0.41
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.077	0.44
Z	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.032	0.32
	Total	......	......	.....	...

[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above

[a] **No failures were recorded at inspections made prior to March 5, 1923; the detail records are accordingly not given here.**

PLATE II.
PROC. AM. SOC. TESTING MATS.
VOL. 24, PART I.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

1919, 1920, 1921, 1922, 1923 AND 1924. SHEETS EXPOSED OCTOBER 17, 1916.
NON-COPPER-BEARING MATERIALS.[1]

Average analysis					Number of Sheets in Test	Date of Inspection			Number of Sheets Failed in Test
Manganese	Phosphorus	Sulfur	Silicon	Copper		Mar. 5, 1923.[a] 77 Months	Oct. 10, 1923. 84 Months	Apr. 18, 1924. 90 Months	
GAGE SHEETS									
0.03	0.119	0.018	0.125	0.319	12	None	None	None	None
0.373	0.011	0.026	0.004	0.237	16	None	None	None	None
0.371	0.095	0.066	0.006	0.247	16	None	None	None	None
0.433	0.085	0.043	0.005	0.234	18	None	None	None	None
0.026	0.005	0.028	0.005	0.236	12	None	None	None	None
0.313	0.009	0.020	0.006	0.223	14	None	None	None	None
0.066	0.008	0.028	0.005	0.239	14	None	None	None	None
0.046	0.007	0.019	0.004	0.299	14	None	None	None	None
0.413	0.109	0.045	.....	0.167	2	None	None	None	None
0.34	0.091	0.036	.....	0.293	3	None	None	None	None
0.305	0.089	0.045	None	0.532	2	None	None	None	None
0.39	0.069	0.072	.....	0.255	3	None	None	None	None
0.363	0.057	0.080	0.002	0.652	2	None	None	None	None
0.42	0.050	0.048	Trace	0.363	2	None	None	None	None
.....	.....	.....	.....	.....	130	None	None	None	None
0.419	0.083	0.042	0.004	0.012	18	None	None	None	None
0.349	0.022	0.048	0.037	0.113	17	None	None	None	None
0.029	0.004	0.032	0.003	0.067	12	None	None	None	None
0.028	0.004	0.027	0.004	0.028	19	None	None	None	None
0.371	0.009	0.029	0.007	0.029	12	None	None	None	None
0.414	0.010	0.029	0.007	0.057	14	None	None	None	None
0.021	0.006	0.021	0.006	0.025	14	None	None	None	None
0.062	0.008	0.030	0.005	0.028	14	None	None	None	None
0.051	0.123	0.019	0.203	0.023	3	None	None	None	None
0.43	0.080	0.031	0.008	0.014	3	None	None	None	None
0.389	0.040	0.027	0.007	0.033	3	None	None	None	None
.....	.....	.....	.....	.....	129	None	None	None	None
SHEETS									
0.27	0.014	0.053	0.006	0.187	9	None	None	None	None
0.028	0.006	0.036	0.003	0.194	9	None	None	None	None
0.034	0.114	0.021	0.134	0.283	11	None	None	None	None
0.387	0.016	0.027	0.004	0.244	16	None	None	None	None
0.365	0.097	0.068	0.008	0.252	16	None	None	None	None
0.447	0.091	0.046	0.004	0.237	16	None	None	None	None
0.419	0.013	0.041	0.011	0.185	14	None	None	None	None
0.313	0.009	0.020	0.005	0.227	14	None	None	None	None
0.074	0.008	0.037	0.005	0.260	14	None	None	None	None
0.051	0.007	0.021	0.005	0.304	14	None	None	None	None
0.37	0.093	0.043	0.009	0.269	3	None	None	None	None
0.38	0.110	0.046	.....	0.527	3	None	None	None	None
0.351	0.045	0.052	0.003	0.187	3	None	None	None	None
0.35	0.050	0.059	0.003	0.264	3	None	None	None	None
0.42	0.052	0.054	Trace	0.641	3	None	None	None	None
.....	.....	.....	.....	.....	148	None	None	None	None
0.386	0.089	0.040	0.007	0.014	14	None	None	None	None
0.38	0.017	0.062	0.036	0.084	3	None	None	None	None
0.028	0.002	0.027	0.002	0.141	3	None	None	None	None
0.026	0.004	0.022	0.002	0.024	7	None	None	None	None
0.536	0.008	0.030	0.249	0.020	12	None	1 (1)	None	1
0.023	0.006	0.022	0.004	0.022	14	None	5 (1)	None	1
0.055	0.007	0.031	0.004	0.027	14	None	None	None	None
0.055	0.139	0.021	0.218	0.020	3	None	None	None	None
0.41	0.102	0.044	0.009	0.013	3	None	None	None	None
0.44	0.095	0.036	0.003	0.140	3	None	None	None	None
0.32	0.063	0.042	.....	0.019	3	None	None	None	None
.....	.....	.....	.....	.....	79	None	2	None	2

above 0.15 per cent copper as copper-bearing.
en here.

copper-bearing and non-copper-bearing metals (the average analysis of all sheets at the Fort Sheridan, Pittsburgh (completed in 1923) and Annapolis locations being the basis for classification), also showing the failures present in each group of sheets at all inspections.

THIRD MEETING

The third meeting of the sub-committee was held in Philadelphia on April 19, 1924, at which time the report of the sub-committee was considered and unanimously approved.

Respectfully submitted on behalf of the sub-committee,

J. H. GIBBONEY,
Chairman.

REPORT OF SUB-COMMITTEE V ON TOTAL IMMERSION TESTS

Sub-Committee V on Total Immersion Tests reports that all of the No. 22 gage sheets, and one of the No. 16 gage sheets in the U. S. Bureau of Standards test racks at Washington, D. C., have failed, and that 86 of the 144 No. 22 gage sheets in the U. S. Naval Engineering Experiment Station test racks at Annapolis, Md., have also failed.

The failures are recorded in the same form as the failures in the Calumet Mine test, given in the *Proceedings* of the Society for 1921.[1]

Table II gives the records of the No. 22 gage sheets in the Bureau of Standards test at Washington.

Table III gives the records of the No. 22 gage sheets which have failed at the Naval Experiment Station at Annapolis.

Table I gives a comparison of the failures of the No. 22 gage sheets in the Calumet Mine test and in the Bureau of Standards test. The average life of the sheets in the Bureau of Standards test was 18½ times as long as the average life of the sheets in the Calumet Mine test.

Table IV gives the temperature and analyses of the water at the Bureau of Standards test at the various inspection dates.

Table V gives the temperature and analyses of the water at the Naval Experiment Station as reported. This data will be more fully reported in the future.

Contrary to the results in the atmospheric tests it is evident in these total immersion tests that the presence of copper is not a factor in the life of the specimens.

Respectfully submitted on behalf of the sub-committee,

WILLIAM A. COOPER,
Chairman.

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[1] *Proceedings*, AM. Soc. Testing Mats., Vol. 21, p. 157 (1921).

TABLE I.—COMPARISON OF FAILURES OF NO. 22 GAGE SHEETS IN CALUMET MINE TEST AND U. S. BUREAU OF STANDARDS TEST.

No. 22 GAGE SHEETS

Group	Designation	Series	Description	Exposed to Running Mine Water, Calumet Mine, Pittsburgh District			Exposed to Running City Water, Bureau of Standards, Washington, D. C.		
				Average Number of Days Before Failure			Average Number of Days Before Failure		
A	Bessemer Steel	A	Non-Copper-Bearing	52.5	55.6	51.7	881.83	899.1	889.63
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	51.33			915.66		
Z1	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	63			899.83		
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	35	47.83		863	880.16	
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	56			853.16		
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	52.5			924.33		
O	Basic Open-Hearth Steel	A	Non-Copper-Bearing	36.16	40.25	44.85	869.66	874.82	867.47
B	Basic Open-Hearth Steel	A	" " "	39.66			881		
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	44.33			873.83		
H	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	39.66	46.16		875.83	863.8	
M	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" "	50.16			760.16		
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	58.33			923.16		
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	38.5			852.66		
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	50.16			873.33		
Z7	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	46.66			897.66		
D	Low-Copper Pure Iron	A	Non-Copper-Bearing	51.33	47.44	46.27	804.50	899.72	933.66
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	43.16			996.66		
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	47.83			898		
C	Copper-Bearing Pure Iron	A	Copper-Bearing	39.66	45.11		854.33	967.61	
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	36.16			1047.16		
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	59.5			1001.33		
K	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	52.5	52.5	52.5	821.83	821.83	821.83
Y	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	46.66	46.66	48.41	740.50	740.50	766
E	Puddled Iron	A	Copper-Bearing	50.16	50.1		791.50	791.50	
	Average Number of Days			47.54			879.2		

NOTE.—Group B in Calumet Test analyzed 0.163 per cent of Copper and was designated Copper-Bearing Basic Open-Hearth Steel, while the specimens in the Bureau of Standards Tests analyzed 0.102 per cent Copper, and were designated Non-Copper-Bearing Basic Open-Hearth Steel, 0.15 per cent of Copper having been decided upon as the limit for Copper-Bearing Steel.

TABLE II.—REPORT ON SUBMERGED TESTS. SHEETS EXPOSED AUGUST 10, 1920, IN RUNNING WASHINGTON CITY WATER AT THE U. S. BUREAU OF STANDARDS, WASHINGTON, D. C.

NO. 22 GAGE SHEETS

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test.
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	
A	Bessemer Steel	A	Non-Copper-Bearing	0.036	0.385	0.091	0.041	0.005	0.013	6
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.060	0.375	0.114	0.049	....	0.014	6
Z1	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.070	0.385	0.085	0.047	0.009	0.131	6
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.041	0.370	0.098	0.068	....	0.241	6
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.028	0.366	0.079	0.034	0.007	0.255	6
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.029	0.360	0.076	0.040	0.009	0.512	6
O	Basic Open-Hearth Steel	A	Non-Copper-Bearing	0.140	0.546	0.007	0.027	0.215	0.014	6
B	Basic Open-Hearth Steel	A	" " "	0.093	0.365	0.017	0.060	0.015	0.102	6
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.096	0.317	0.069	0.044	0.002	0.018	6
H	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	0.067	0.410	0.026	0.026	....	0.238	6
M	Open-Hearth Steel, Alan Wood Iron and Steel Co	B	" "	0.091	0.435	0.010	0.039	0.007	0.187	6
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.083	0.316	0.008	0.023	0.003	0.206	6
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.360	0.048	0.057	....	0.210	6
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.395	0.056	0.056	....	0.294	6
Z7	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.410	0.043	0.043	....	0.576	6
D	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.035	0.022	0.004	0.021	....	0.026	6
X	Low-Copper Pure Iron, Inland Steel Co	B	" " "	0.017	0.057	0.006	0.031	....	0.025	6
S	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.020	0.016	0.005	0.024	0.004	0.018	6
C	Copper-Bearing Pure Iron	A	Copper-Bearing	0.025	0.023	0.004	0.030	0.007	0.175	6
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.012	0.066	0.008	0.039	0.002	0.258	6
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.016	0.048	0.006	0.021	....	0.301	6
K	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.103	0.459	0.087	0.045	....	0.236	6
Y	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.063	0.156	0.020	0.230	0.023	6
E	Puddled Iron	A	Copper-Bearing	0.031	0.035	0.117	0.021	0.140	0.304	6
										144

TABLE II.—*Continued.*—REPORT OF SUBMERGED TESTS. SHEETS EXPOSED AUGUST 10, 1920, IN RUNNING WASHINGTON CITY WATER AT THE U. S. BUREAU OF STANDARDS, WASHINGTON, D. C.

NO. 22 GAGE SHEETS

Group	Failures on Date of Inspections													Average Number of Days		
	July 11, 1922, 700 Days	Sept. 8, 1922, 759 Days	Oct. 19, 1922, 800 Days	Dec. 2, 1922 843 Days	Jan. 22, 1923, 894 Days	Feb. 26, 1923, 929 Days	Mar. 29, 1923, 960 Days	Apr. 29, 1923, 991 Days	June 2, 1923, 1025 Days	July 5, 1923, 1058 Days	Aug. 13, 1923, 1097 Days	Sept. 13, 1923, 1128 Days	Oct. 12, 1923, 1157 Days			
A			45 46	41	44	39			43					881.83	899.1	889.63
Z				11 11	7	7	11		7					915.66		
Z1					112 112 113 113 113	112								899.83		
I		51		36	39 42 45 48									863	880.16	
Z2		214	213	214	213 214	213								853.16		
Z3				314	314	310 314	310	310						924.33		
O		32 34	36	35		33						31		869.66	874.82	867.47
B	38			30	36	32 34		29						881.		
Z4	424		423		422	421 421		422						873.83		
H	50		53	41	44		47			38				875.83	863.8	
M	31 40	33 35	38	29										760.16		
T						35	36		40 41					923.16		
Z5	509	509	38 39	509	508	508		508						852.66		
Z6		605	607		607	605 605 607								873.33		
Z7			715 715	714	714			715		714				897.66		
D	41 42	33	40	36					37					804.50	899.72	933.66
X				30		35 39			33		41		32	996.66		
S		32	38	27		30	34				36			898.		
C	36		32	26	28	34	30							854.33	967.61	
U							35		33 88	31 40			29	1047.16		
V				37			39		30 33	42	27			1001.33		
K		42	39 44 48	36		46								821.83	821.83	
Y	7 7 8 9		8	9										740.50	740.5	766.
E	36	28 32 34		26		30								791.50	791.5	
	14	14	19	20	21	22	8	5	10	5	3	1	2			

Average = 879.2 days.

TABLE III.—REPORT ON SUBMERGED TESTS. SHEETS EXPOSED JUNE 2, 1920, IN RUNNING SEVERN RIVER WATER AT THE NAVAL ENGINEERING EXPERIMENT STATION, ANNAPOLIS, MD.

No. 22 GAGE SHEETS

Group	Designation	Series	Description	Average Analysis, per cent.						Number of Sheets in Test
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	
A	Bessemer Steel	A	Non-Copper-Bearing	0.034	0.373	0.093	0.035	0.0065	0.016	6
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.067	0.400	0.104	0.046	0.009	0.013	6
Z1	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.077	0.435	0.096	0.036	0.003	0.139	6
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.053	0.344	0.096	0.066	0.0035	0.249	6
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.388	0.095	0.041	....	0.266	6
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.051	0.366	0.112	0.052	....	0.541	6
O	Basic Open-Hearth Steel	A	Non-Copper-Bearing	0.115	0.512	0.010	0.029	0.251	0.014	6
B	Basic Open-Hearth Steel	A	" " "	0.034	0.226	0.0115	0.055	0.0045	0.144	6
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.077	0.351	0.068	0.055	0.004	0.185	6
H	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	0.085	0.367	0.011	0.027	0.0025	0.252	6
M	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.099	0.391	0.012	0.042	0.012	0.188	6
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.078	0.322	0.0095	0.019	0.010	0.237	6
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.350	0.047	0.0535	0.003	0.189	6
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.320	0.046	0.064	0.003	0.263	6
Z7	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.070	0.415	0.049	0.051	Trace	0.634	6
D	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.022	0.024	0.0038	0.024	0.002	0.026	6
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.011	0.065	0.006	0.029	0.003	0.033	6
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.011	0.015	0.006	0.022	0.007	0.022	6
C	Copper-Bearing Pure Iron	A	Copper-Bearing	0.025	0.036	0.0066	0.035	0.002	0.194	6
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.078	0.008	0.039	0.004	0.253	6
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.013	0.068	0.007	0.022	0.005	0.306	6
K	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.111	0.435	0.087	0.045	0.0027	0.220	6
Y	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.053	0.149	0.021	0.220	0.020	6
E	Puddled Iron	A	Copper-Bearing	0.039	0.032	0.114	0.021	0.110	0.241	6
										144

TABLE III. (*Continued.*)—REPORT ON SUBMERGED TESTS. SHEETS EXPOSED JUNE 2, 1920, IN RUNNING SEVERN RIVER WATER AT THE NAVAL ENGINEERING EXPERIMENTAL STATION, ANNAPOLIS, MD.

No. 22 GAGE SHEETS

Group	Failures on Date of Inspections											Average Number of Days
	Oct. 18, 1922, 868 Days	April 14, 1923, 1046 Days	June 8, 1923, 1101 Days	July 11, 1923, 1134 Days	Aug. 17, 1923, 1171 Days	Sept. 17, 1923, 1202 Days	Oct. 18, 1923, 1232 Days	Nov. 19, 1923, 1264 Days	Dec. 21, 1923, 1296 Days	Jan. 22, 1924, 1328 Days	March 4, 1924, 1370 Days	
A						2	9				4 5	
Z					1 2		3					
Z1			102		102 108		102		108		108	1223.5
I						1	3	15				
Z2		207			204			204				
Z3								301	301			
O		2 5	4 7		3			9				1121.5
B												
Z4		417				413	417		416		413	
H					2 5							
M			4	7	9		13					
T		24	4		22		2					
Z5		501				503	503 503	501				
Z6			603		602		602			603		
Z7		705			707							
D		1 15				4						
X		3 12	1				9					
S		2 4		6	8 10				12			1144
C		2 10									5	
U								3 11		13		
V		2			8	10			4	6		
K					3						6	
Y	1	1 2		2 3								
E										2	4	
	1	18	7	4	16	6	11	7	5	4	7	

TABLE IV.—TEMPERATURE AND ANALYSES OF WASHINGTON CITY WATER FLOWING IN THE TOTAL IMMERSION TESTS AT THE U. S. BUREAU OF STANDARDS.

Date of Sampling	Temperature, deg. Cent.	Alkalinity in Terms of Calcium Carbonate (Methyl Orange), parts per million	Dissolved Oxygen, cc. per liter		P. H. (Phenol Red)
			No. 16 Gage Tank	No. 22 Gage Tank	
September 10, 1920	24.5	64	4.36	4.55	...
October 28, 1920	18.5	81	5.43	5.40	...
November 20, 1920	15.0	75	6.15	6.24	...
December 12, 1920	10.5	95	5.56	5.62	...
January 24, 1921	6.0	90	7.70	7.58	...
February 12, 1921	6.5	52	6.52	6.54	...
March 8, 1921	11.0	46	5.00	4.82	...
April 26, 1921	19.0	61	5.20	5.11	...
May 25, 1921	21.0	73	5.37	5.50	...
June 17, 1921	26.0	63	4.20	4.58	...
July 18, 1921	28.5	67	3.36	3.50	...
August 21, 1921	28.0	78	3.52	3.61	...
September 16, 1921	27.0	85	3.92	3.75	...
October 20, 1921	18.0	79	5.24	5.30	...
November 25, 1921	12.0	85	6.40	6.31	...
December 19, 1921	8.5	45	5.60	5.72	...
January 19, 1922	7.0	40	8.61	8.60	...
February 16, 1922	4.0	35	8.80	8.70	...
March 21, 1922	11.0	35	7.48	7.51	...
April 26, 1922	17.5	55	5.90	5.75	...
May 23, 1922	22.5	59	4.91	4.20	...
June 24, 1922	25.0	56	4.32	4.51	...
July 26, 1922	28.0	60	3.57	3.71	...
August 20, 1922	28.0	62	3.47	3.29	...
September 21, 1922	27.0	81	3.90	3.81	...
October 14, 1922	22.0	80	4.25	4.31	...
November 20, 1922	18.0	97	5.78	5.65	...
December 20, 1922	11.0	105	5.84	5.78	...
January 20, 1923	8.0	65	6.73	6.81	...
February 6, 1923	5.0	55	6.09	7.04	...
March 29, 1923	10.5	48	5.98	5.54	...
April 20, 1923	15.0	50	4.25	4.64	...
May 24, 1923	21.5	55	3.08	3.44	...
June 20, 1923	27.0	62	3.13	3.52	...
July 14, 1923	28.0	70	3.50	3.52	...
August 20, 1923	28.0	68	2.01	2.12	...
September 20, 1923	23.0	80	4.03	3.80	...
October 20, 1923	19.0	66	2.91	3.51	...
November 20, 1923	11.0	95	5.44	....	...
December 20, 1923	10.0	65	5.74	....	...
January 23, 1924	6.0	31	8.44	....	7.0
March 9, 1924	9.0	42	7.47	....	7.1

TABLE V.—TEMPERATURE AND ANALYSES OF SEVERN RIVER WATER AT ANNAPOLIS, MD., FLOWING IN THE TOTAL IMMERSION TESTS AT THE NAVAL ENGINEERING EXPERIMENT STATION.

SAMPLE TAKEN AT 12 NOON ON NOVEMBER 19, 1923.	ANALYSIS, P. P. M. (MG. PER LITER.)
Bicarbonate (HCO_3)	85.2
Chloride (Cl)	8440
Sulphate (SO_4)	1169
Carbonate (CO_3)	None
Sodium and potassium calculated as:	
Sodium (Na)	4782
Calcium (Ca)	192
Magnesium (Mg.)	567
Iron Oxide and Alumina (Fe_2O_3 and Al_2O_3)	3.1
Silica (SiO_2)	2.3
Total dissolved solids dried at 180° C.	15491

Date of Sampling	Temperature, deg. Cent.	Alkalinity in Terms of Calcium Carbonate (Methyl Orange), p. p. m.	Dissolved Oxygen, cc. per liter		P. H. (Phenol Red)
			No. 16 Gage Tank	No. 22 Gage Tank	
December 21, 1923	8.3	59	3.80	3.55	...
January 22, 1924	1.1	49	6.40	6.38	7.4
March 4, 1924	3.3	57	6.63	6.85	7.5

REPORT OF SUB-COMMITTEE VI ON SPECIFICATIONS FOR GALVANIZED SHEETS

Sub-Committee VI has held one formal meeting and has carried on considerable discussion by correspondence, and presents herewith proposed Tentative Specifications for Hot-dipped Galvanized Sheets.

These specifications as appended hereto[1] are offered as an advance step in the development of satisfactory requirements for the purchase of this class of commodity. The sub-committee has in mind to add requirements for the composition of the base metal for the four types of metal included in the scope of the specifications and hopes to have such requirements ready for consideration at the end of another year.

The sub-committee now expects to devote its attention to the development of requirements for sheets coated with zinc by the sherardizing process.

Respectfully submitted on behalf of the sub-committee,

H. E. SMITH,
Chairman.

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[1] See p. 775.—ED.

REPORT OF SUB-COMMITTEE VII ON ACCELERATED TESTS

Sub-Committee VII on Accelerated Tests, which was organized at the time of the last annual meeting, has held two meetings during the past year, at Annapolis in October and at Pittsburgh in March.

The laboratory methods for accelerated corrosion reported upon and discussed at these meetings include the following: (*a*) simple immersion in aërated and in unaërated solutions, (*b*) repeated immersion in the same solutions, that is, a continuous series of short cycles each consisting of immersion beneath the surface of the liquid immediately followed by withdrawal into the air, (*c*) interrupted repeated immersion, an interval for the drying of the specimens between successive immersions being provided for, (*d*) spray or mist test, and (*e*) a simulated atmospheric test. These methods and the apparatus employed will be described somewhat in detail in a technical paper presented before the Society at this meeting.[1] This paper should properly be considered as a joint contribution from Committee A-5 on Corrosion of Iron and Steel and Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys.

The first laboratory work to be undertaken will be upon galvanized sheet material, a supply of such material specially prepared for the use of the coated metals sub-committee of the Federal Specifications Board being available for use. The following liquids: distilled water, dilute sulfuric acid, aqueous solution of sodium chloride and of ammonium nitrate will be used in each of the first four methods of test. The results of these tests, it is hoped, will show which are most suitable for general use and these particular tests will be applied to the materials which are to be assembled for field tests by Sub-Committee VIII. The simulated atmospheric corrosion test will also be used for all the materials to be exposed in the field tests. The main purpose of the sub-committee is to find some test which will give results indicative of what really occurs in service.

Respectfully submitted on behalf of the sub-committee,

HENRY S. RAWDON,
Chairman.

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[1] H. S. Rawdon, A. I. Krynitsky and W. H. Finkeldey, "Types of Apparatus Used in Testing the Corrodibility of Metals," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

REPORT OF SUB-COMMITTEE VIII ON TESTS OF METALLIC COATINGS

Sub-Committee VIII on Tests of Metallic Coatings has held two meetings during the past year: at Annapolis in October, and at Pittsburgh in March.

At the October meeting, it was decided to undertake comprehensive field tests, at several locations representing varying atmospheric conditions, of metal products coated by the following methods:

Hot-dip galvanizing;
Sherardizing;
Electro-zinc plating;
Zinc coating by spraying;
Cadmium plating;
Calorizing;
Chromium plating;
Terne coating.

It was apparent that some of the selected processes of coating had not developed as yet in an outstanding large commercial way; however, the more general use of these special coatings seemed to indicate a need for tests that would be representative of the development of the various types of coating up to the present time.

In selecting forms for test specimens for the exposure tests it was decided that such pieces in the case of sheet metal should be of the full commercial size, wherever practical, smaller sizes only when necessary to meet other controlling conditions. The following weights of coatings were adopted for zinc-coated products:

> Hot-dip galvanizing should be $1\frac{1}{4}$, $1\frac{3}{4}$ and $2\frac{1}{2}$ oz. per sq. ft. of sheet metal for both coated surfaces.
>
> Sherardized coatings should be $2\frac{1}{2}$ mils in thickness on each coated side.
>
> The terne plating should be long terne, 8 and 20 lb. per double base box of 112 sheets, 20 by 28 in.
>
> The electro-zinc, chromium and cadmium plating, calorizing and zinc coating by the spraying process, should be representative of the present best developed commercial practice.

The base sheet metal for all tests is to be No. 22 gage, basic open-hearth steel, without copper, and all sheets are to be obtained from one heat of steel. In addition to the coated sheets, castings of an approved form made of both cast and malleable iron are to be coated for exposure.

Wire test specimens of material to be determined by further consultation with the coated-wire industry will be included in the tests.

In all cases uncoated control pieces are to be exposed.

The following locations were reported as available for exposure test racks and were tentatively approved by the sub-committee:

(*a*) The New Jersey Zinc Co.'s property at Palmerton, Pa.;
(*b*) The Paint Testing Station of the Pennsylvania Railroad System, at Altoona, Pa.;
(*c*) The Port Morris Power Station of the New York Central Railroad;
(*d*) A semi-tropical location, such as the sea coast in Cuba and Houston, Texas.

The tests will be extended to include other locations, as satisfactory sites for exposure test racks become available.

It was estimated that the successful launching of these tests would require an expenditure of about $6000. However, the great importance of developing reliable service information on the subject as a guide for proper standardization of the many classes of metallic-coated products included in this investigation seemed to justify the undertaking and insure for it the hearty cooperation of the producers and users of such materials.

Respectfully submitted on behalf of the sub-committee,

F. A. HULL,
Chairman.

REPORT OF COMMITTEE A-6
ON
MAGNETIC PROPERTIES

Committee A-6 in its several meetings has considered two specific problems:

1. The present tentative methods.
2. Specifications for material.

The committee recommends that the Tentative Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 23 T)[1] be advanced to standard with the following modifications:

In Section 14 (*c*), omit the words "secure each bundle by string or tape (not wire) and," and insert a note, "If desired, for convenience, the bundles may be loosely secured by tape or string (not wire)."

The definitions of terms appearing in the methods have received a review by Committee E-8 on Nomenclature and Definitions and have been approved by that committee. The methods, when adopted as standard, will supersede the present Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 18).[2]

The discussion of the specifications of the magnetic and other properties of iron and steel as required in the construction of electrical and magnetic equipment confirmed the decision which has been reached each time the committee has considered this matter in the past, namely, that the time is not ripe for the preparation of such specifications.

This report has been submitted to letter ballot of the committee, which consists of 11 members, of whom 9 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

CHARLES W. BURROWS,
Chairman.

R. L. SANFORD,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Methods of Test for Magnetic Properties of Iron and Steel, submitted in 1923, and amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, **Part 1**, p. 560 (1923).

[2] 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE A-7
ON
MALLEABLE CASTINGS

During the past year the committee has been confronted with the depressing necessity of selecting a new chairman, due to the sudden death of Mr. H. E. Diller. A nominating committee of three was appointed and a letter ballot cast for chairman and secretary for the next two years. Mr. W. P. Putnam was elected chairman, and the present secretary re-elected.

In addition to the election to membership of Mr. G. A. Drysdale, metallurgical editor of *The Foundry* and the successor to Mr. Diller on that publication, and Mr. H. Bornstein, chief chemist of Deere and Company, it has been decided to invite someone connected with the General Motors Company to accept membership on the committee.

At a meeting of the committee held on June 26, unanimous action was taken to recommend the adoption as standard of the tentative revisions in the Standard Specifications for Malleable Castings (A 47 – 19), which revisions have been published as tentative in the Proceedings of the Society.[1]

It is planned to hold a meeting in Milwaukee in October at the time of the American Foundrymen's Association convention, to discuss the advisability, after canvassing the matter thoroughly prior to that meeting, of whether it would be advisable to recommend separate specifications for different grades of malleable iron. Also, the advisability of incorporating in the present specifications a certain heat treatment for such castings as were to be subsequently hot galvanized.

The following resolution was adopted unanimously:

"BE IT RESOLVED, That Committee A-7 express to the Society their great sorrow in the loss the committee and the Society sustained through the death of Mr. H. E. Diller, whose ability, sterling qualities and kindly disposition so endeared him to all with whom he ame in contact."

Respectfully submitted on behalf of the committee,

ENRIQUE TOUCEDA,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Malleable Castings, proposed in 1922, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 958 (1923).

REPORT OF COMMITTEE A-8

ON

MAGNETIC ANALYSIS

The main activities of Committee A-8 on Magnetic Analysis are centered in its Sub-Committee on Drill Testing. This sub-committee held a meeting in Philadelphia on February 6, 1924, and in addition there have been conferences between individual members for the purpose of discussing the results obtained in the test program as this work proceeded. As stated in the report for 1923, the committee has been endeavoring to establish the relation of practical value, if any, that exists between the magnetic and the cutting properties of a tool. For the purpose, it selected a twist drill of high-speed steel. This is an important article of manufacture and one that, because of its relatively simple form, did not appear to present magnetic testing difficulties.

It was not possible at the meeting last year to detail in an orderly manner the work accomplished and the results obtained up to that time. This year, however, there is presented at this meeting, under the auspices of the committee and by one of its members, a paper[1] which discusses the data for the first lot of twist drills examined. The paper gives, in necessarily brief form, the results of electrical resistance, magnetic, hardness and drilling tests on fifty-one drills of high-speed steel, variously heat treated. While the data are inconclusive from the magnetic correlation viewpoint, the information as a whole is deemed sufficiently important to publish. This is one of a series of papers to be published by individual members of the committee as its work proceeds.

With reference to the data contained in the paper offered this year, we quote from the committee report of 1923:

> "From the standpoint of a correlation of magnetic and mechanical characteristics, the test results so far obtained are to quite an extent negative in character but some promise is found in results obtained by one of the members under alternating magnetomotive forces, in which a distinction is apparently made between hysteresis and eddy current effects. In some instances the agreement is striking, and as the procedure employed seems capable of considerable refinement, it is the opinion of the sub-committee that the work should be continued. It is proposed to obtain a new lot of drills and to make further tests with special reference to the type of test mentioned above."

The new lot of drills referred to has engaged the attention of the sub-committee during the past year. These drills are twenty-seven in number, of $\frac{21}{32}$-in. high-speed steel with carbon-steel shank. As before, they were subjected to various heat treatments. A large number of tests on this second lot has been concluded by one of the members of the sub-committee. These were directed toward determining the actual magnetic characteristics measured under the applied alternating magnetomotive forces and the relative advantages of alternating magnetic and electrical resistance tests. While no hardness or drilling tests have yet been conducted on these drills, some reasonably reliable information may be derived based upon the heat treatments, which were very carefully carried out.

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[1] W. B. Kouwenhoven, "Magnetic Tests of A.S.T.M. Drills," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

Examination of all the results now in hand indicate that the magnetic quantities measured under our alternating magnetomotive force tests are proportional to permeability and hysteresis loss and that a distinction may be made between these two quantities in such manner as to distinguish, to quite an extent, between the quenching and the drawing temperatures to which a tool has been subjected. However, the procedure as at present laid down is subject to limitations in that a reversal of magnetic characteristics apparently takes place after a certain degree of quench or draw is reached, for a given material. Tests of electrical resistance under alternating currnet give results which indicate a limitation of the same kind as the magnetic test, but not to the same extent, the apparent reversal taking place only after a relatively high quench.

In the course of the work on these second drills, information was obtained which indicated that further testing under higher frequencies and lower magnetizing forces may give results of value and remove the limitations now observed. But, above all, the test results have served to crystallize the opinion of the committee that this investigation is essentially one of research and that therefore it is highly important, as the next step, to carefully scrutinize the inherent magnetic and electrical characteristics of high-speed steel. The decision has been reached to obtain a series of specimens of this steel, of uniform cross-section, which will permit of the determination of the fundamental magnetic and other physical data under various conditions of heat treatment.

The Westinghouse Electric and Manufacturing Co. has kindly offered to supply the material and to carry out the heat treatments, and some 150 lb. of ½-in. square high-speed steel will shortly be available for the use of the committee.

This report has been submitted to letter ballot of the committee, which consists of 15 members, of whom 10 have voted affirmatively, none negatively, and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

R. L. SANFORD,
Secretary.

FRANK P. FAHY,
Chairman.

REPORT OF COMMITTEE A-9

ON

FERRO-ALLOYS

The members of Committee A-9 met at the call of the Secretary-Treasurer of the Society at Philadelphia on November 2, 1923, and effected organization. Represented at this initial meeting were nine non-producers and six producers of ferro-alloys and subsequently four non-producers and one producer accepted the invitation extended to become members of this committee, making a total membership of twenty.

Sub-Committees.—There were appointed sub-committees on specifications, on methods of sampling and on methods of analysis for ferro-alloys. These sub-committees are working in their respective fields and report satisfactory progress.

Standards and Tentative Standards.—The committee has under consideration a tentative standard for methods of sampling of ferro-alloys.

The work otherwise is definitely under way and proceeding favorably. It is expected that a complete series of ferro-alloy specifications will have been prepared for submission to the Society at the next annual meeting.

Respectfully submitted on behalf of the committee,

F. C. Langenberg,
Chairman.

Charles McKnight, Jr.,
Secretary.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS

The work accomplished during the past year may be summarized as follows. Under the heading of revisions, changes have been made in the Specifications for Copper, Brass and Copper Pipe, Manganese Bronze, and Aluminum Casting Alloys. New tentative specifications have been drawn up for Seamless Muntz Metal Condenser Tubes, 70–30 Brass Condenser Tubes, Manganese Bronze Castings, Phosphor Tin, Phosphor Copper and Silicon Copper.

In addition to the above work on specifications, other matters have been considered, namely, the present wrought light aluminum alloys commercially available and methods in commercial use to-day for designating lead pipe sizes.

The work of the committee can best be summarized by giving the reports of the various sub-committees which were accepted at the last meeting of the committee, which was held on March 13. They were in substance as follows:

REPORT OF SUB-COMMITTEE I ON PURE METALS IN INGOT FORM

Three meetings of the sub-committee were held during the year: One at the annual meeting of the Society at Atlantic City, June, 1923, one in New York City, January 21, 1924, and one in Pittsburgh, on March 12, 1924.

On account of the tendency on the part of consumers to specify limits for specific impurities in copper, which is entirely unnecessary for electrolytic and lake copper when a high assay and low resistivity value is specified, a sub-committee of producers was appointed to make recommendations as to whether specifications B 4 – 13 and B 5 – 13 covering Lake and electrolytic copper should be revised. This special sub-committee was unable to agree on a recommendation and the matter was taken up by the sub-committee as a whole.

After careful consideration Sub-Committee I recommends the following tentative revision of Specifications B 4 – 13 and B 5 – 13:

Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (B 4 – 13):[1]

Section 4 (a).—Change the first sentence in the second paragraph to read as follows by the addition of the italicized figures and the omission of those in brackets:

> "Low Resistance Lake wire bars shall have a resistivity not to exceed [0.15535] *0.15436* international ohms per meter-gram at 20° C. (annealed)."

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[1] 1921 Book of A.S.T.M. Standards.

Section 5 (a).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Low Resistance Lake copper shall have a purity of at least [99.880] *99.900* per cent as determined by electrolytic assay, silver being counted as copper."

Section 5 (b).—Change the first sentence to read as follows by the addition of the italicized figures and the omission of those in brackets:

"High Resistance Lake copper shall have a purity of at least [99.880] *99.900* per cent, copper, silver, and arsenic being counted together."

Section 9.—Change the second paragraph from its present form: namely,

"In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately ½ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final."

to read as follows:

"In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five holes, approximately ½ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

"The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

"Each party shall make an analysis by the Standard Method of Battery Assay of Copper (B 34 – 20) of the American Society for Testing Materials and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final."

Committee B-2 recommends that these revisions be accepted for publication as tentative.

Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (B 5 - 13):[1]

Section 3 (a).—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

"*Metal Content.*—The copper in all shapes shall have a purity of at least [99.880] *99.900* per cent, as determined by [electrolytic assay] *the A.S.T.M. Standard Method of Battery Assay of Copper (B 34 - 20)*, silver being counted as copper."

Section 3 (b).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"*Resistivity.*—All wire bars shall have a resistivity not to exceed [0.15535] *0.15436* international ohms per meter-gram at 20° C. (annealed); all ingot and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed)."

Section 7.—Change the second paragraph from its present form: namely,

"In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately ½ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final."

to read as follows:

"In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five holes approximately ½ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

"The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

"Each party shall make an analysis and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final."

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[1] 1921 Book of A.S.T.M. Standards.

Committee B-2 recommends that these revisions be accepted for publication as tentative.

Sub-Committee I recommends that no limitation of specific impurities be made in Specifications B 4 and B 5 since the purity and resistivity requirements are sufficient to govern the quality of electrolytic and of lake copper.

REPORT OF SUB-COMMITTEE II ON WROUGHT METALS AND ALLOYS

Certain criticisms of a minor nature have been made of the Tentative Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 23 T).[1] After full discussion it was decided to consider that these criticisms involved matters of a clerical nature only and did not involve changes of either form or substance and it was decided to correct the specifications accordingly. These corrections are as follows:

Section 13.—Change 70° F. to 68° F.

Note 1.—Add two sentences to read as follows:

"Owing to the fact that a minimum of 1 per cent tin has heretofore existed, cases will occur, until the present standards become universal, where the tin may exceed the 1.20 per cent maximum. It is not considered that this would be harmful or should be made a cause of rejection."

Replace the micrographs shown by two new micrographs, etched with $NH_4OH + H_2O_2$, prepared by W. H. Bassett, as shown on page 797.

The tentative specifications as corrected are recommended for advancement to standard.

Specifications for seamless Muntz metal and 70–30 brass condenser tubes, having been requested, were prepared by the sub-committee and after discussion, amendment, and correction were adopted, as appended hereto,[2] and are recommended for acceptance as tentative standards.

Attention has been called to the fact that the Standard Specifications for Brass and Copper Pipe (B 43 – 23)[3] and (B 42 – 23),[3] contain no table of dimensions for extra strong pipe. After discussion, it was decided to amend the above mentioned specifications by adding to the table of standard sizes appearing in Section 13 the necessary dimensions and weights covering extra strong pipe, as given in the accompanying Tables I and II. Committee B-2 recommends that the specifications be revised accordingly and asks for the necessary nine-tenths vote of the Society to secure the adoption of

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 587 (1923).

[2] See pp. 794-801.—ED.

[3] **A.S.T.M. Standards Adopted in 1923.**

TABLE I.—REVISED TABLE OF STANDARD WEIGHTS AND DIMENSIONS FOR BRASS PIPE.

Size of Pipe, in.	Standard Pipe			Extra Strong Pipe	
	Outside Diameter, in.	Thickness, in.	Nominal Weight, lb. per foot of length	Thickness, in.	Nominal Weight, lb. per foot of length
⅛	0.405	0.0620	0.246	0.100	0.353
¼	0.540	0.0825	0.437	0.123	0.593
⅜	0.675	0.0905	0.612	0.127	0.805
½	0.840	0.1075	0.911	0.149	1.19
¾	1.050	0.1140	1.24	0.157	1.62
1	1.315	0.1265	1.74	0.182	2.39
1¼	1.660	0.1460	2.56	0.194	3.30
1½	1.900	0.1500	3.04	0.203	3.99
2	2.375	0.1565	4.02	0.221	5.51
2½	2.875	0.1875	5.83	0.280	8.41
3	3.500	0.2190	8.31	0.304	11.24
3½	4.000	0.2500	10.85	0.321	13.67
4	4.500	0.2500	12.29	0.341	16.41
4½	5.000	0.2500	13.74	0.375	20.07
5	5.563	0.2505	15.40	0.375	22.52
6	6.625	0.2500	18.44	0.437	31.32
7	7.625	0.2815	23.92	0.500	41.23
8	8.625	0.3125	30.05	0.500	47.02
9	9.625	0.3440	36.94	0.500	52.81
10	10.750	0.3655	43.91	0.500	59.32

TABLE II.—REVISED TABLE OF STANDARD WEIGHTS AND DIMENSIONS FOR COPPER PIPE.

Size of Pipe, in.	Standard Pipe			Extra Strong Pipe	
	Outside Diameter, in.	Thickness, in.	Nominal Weight, lb. per foot of length	Thickness, in.	Nominal Weight, lb. per foot of length
⅛	0.405	0.0620	0.259	0.100	0.371
¼	0.540	0.0825	0.460	0.123	0.624
⅜	0.675	0.0905	0.643	0.127	0.847
½	0.840	0.1075	0.957	0.149	1.25
¾	1.050	0.1140	1.30	0.157	1.71
1	1.315	0.1265	1.83	0.182	2.51
1¼	1.660	0.1460	2.69	0.194	3.46
1½	1.900	0.1500	3.20	0.203	4.19
2	2.375	0.1565	4.23	0.221	5.79
2½	2.875	0.1875	6.14	0.280	8.84
3	3.500	0.2190	8.75	0.304	11.82
3½	4.000	0.2500	11.41	0.321	14.37
4	4.500	0.2500	12.94	0.341	17.25
4½	5.000	0.2500	14.46	0.375	21.10
5	5.563	0.2505	16.21	0.375	23.67
6	6.625	0.2500	19.41	0.437	32.93
7	7.625	0.2815	25.17	0.500	43.34
8	8.625	0.3125	31.63	0.500	49.42
9	9.625	0.3440	38.83	0.500	55.56
10	10.750	0.3655	46.22	0.500	62.40

the revisions as standard without having them first published as tentative.

The sub-committee has been requested to prepare specifications for Muntz metal condenser tube plates and to prepare an amendment to the Standard Specifications for High Sheet Brass (B 36 – 21), so that the table of thicknesses and tolerances will agree with those adopted by the Ordnance Department. These two questions are in the hands of the sub-committee for development.

REPORT OF SUB-COMMITTEE III ON SAND-CAST METALS AND ALLOYS

Sub-Committee III has held two meetings during the year. The subject of standard test bars for cast non-ferrous alloys has had its earnest consideration. As reported last year, eleven investigators have indicated their willingness to conduct experiments on the bar suggested by the committee. Two more investigators have since offered their services, making in all, thirteen.

The bar suggested for experimenting as given in the report for 1923[1] has proved very satisfactory on red brasses and bronzes, but it is evident that it will need modification or possibly entire change for alloys such as manganese bronze, aluminum bronze, and other high shrinkage alloys of this character.

The subject of acid-resisting alloys was brought to the committee's attention, and is having its consideration. In view of the work that Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys is doing on corrosion of non-ferrous alloys, it seems advisable to withhold the drawing up of specifications for acid-resisting alloys until such time as Committee B-3 has a little more definite information to offer on the details of corrosion. This view of the sub-committee is borne out by the wide diversity of opinion as to the effectiveness of any one given alloy to withstand certain acid conditions.

The fact that the Standard Specifications for Manganese-Bronze Ingots for Sand Castings (B 7 – 14)[2] were not entirely up-to-date was brought out by one of our large manufacturers of manganese bronze ingots for sand castings. The sub-committee, therefore, recommends the withdrawal of these specifications from standard and their withdrawal from the Engineering Standards Committee. In a recent meeting of Sub-Committee III, these specifications were carefully considered, and the committee now offers as tentative the revised Specifications for Manganese-Bronze Ingots for Sand Castings appended hereto.[3]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 177 (1923).

[2] 1921 Book of A.S.T.M. Standards.

[3] See p. 789.—ED.

The committee also offers for publication as tentative the Specifications for Manganese-Bronze Sand Castings appended hereto.[1]

REPORT OF SUB-COMMITTEE IV ON WHITE METALS

The effect of impurities on the properties of Babbitt metal has been studied by Mr. Freeman, of the U. S. Bureau of Standards, and his report is given as Appendix I to this report. The sub-committee is trying to arrange for research work along this line covering the effects of impurities on friction and wearing properties, fluidity, brittleness, and amount of drossing. The sub-committee recommends that the values given in the Appendix to the Specifications for Babbitt Metal (B 23 – 18 T)[2] be changed to conform to the work done at the Bureau of Standards.

This work is reported in Appendix I to the Report of Committee B-2 for 1922, *Proceedings*, Vol. 22, Part I, page 207.

REPORT OF SUB-COMMITTEE VI ON NON-FERROUS ALLOYS FOR RAILROAD USE

The chairman advised that the American Railway Association did not favor the formation of a joint committee on non-ferrous alloys for railroad use and that his sub-committee was therefore engaged in reviewing the two specifications, A.S.T.M. (Specifications B 17 – 21 T) and A.R.A. to see whether reconciliation could be effected. Certain changes, largely in the chemical analysis, were recommended.

REPORT OF SUB-COMMITTEE VII ON METHODS OF CHEMICAL ANALYSIS

Progress is reported on developing methods for the determination of small amounts of impurities in zinc and methods for determination of small amounts of aluminum in bronze.

The sub-committee recommended the advancement to standard of the tentative revision of the Standard Methods of Chemical Analysis of Pig Lead (B 35 – 20).[3] It is also recommended that the Methods of Chemical Analysis for Aluminum and Light Aluminum Alloys (B 40 – 23 T) remain tentative for another year.

REPORT OF SUB-COMMITTEE VIII ON ALUMINUM ALLOYS

A revision of the Standard Specifications for Aluminum Casting Alloys (B 26 – 21)[3] covering Sections 3 and 5 as regards the requirements for chemical analysis and physical properties is submitted as follows:

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[1] See p. 791.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 538 (1920).

[3] 1921 Book of A.S.T.M. Standards.

Section 3.—Change the table covering the requirements for chemical composition from its present form: namely,

Alloy	Copper, per cent	Zinc, per cent	Manganese, per cent	Maximum Total Impurities, per cent	Aluminum, per cent
A	7 - 8.5	......	......	1.7	Remainder
B	8.5 - 11	......	......	1.7	Remainder
C	11 - 14	......	......	1.7	Remainder
D	2.5 - 3.0	12.5 - 14.5	......	1.7[a]	Remainder
E	2 - 2.5	......	0.75 - 1.25	1.0	Remainder

[a] Lead content shall not be greater than 0.1 per cent.

to conform to the following:

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Manganese, per cent	Zinc, per cent	Remarks
A	not under 96.5	1 to 1.5	not over 0.5	not over 0.5	trace	0.7 to 2.0	trace	
B	not under 92.5	not over 0.6	not over 1.0	4.5 to 6.0	trace	not over 0.2	not over 0.20	
C	not under 90.0	7 to 8.5	......	......	......	......	not over 0.20	Total of Fe, Si, Mn, Zn and Sn not to exceed 1.70 per cent.
D	88 to 92	6 to 8.0	not over 1.50	......	......	......	not over 2.50	Total of Si, Mn, and Sn not to exceed 1.00 per cent.

Section 5.—Change the table covering the requirements for tensile properties from its present form: namely,

Alloy	Minimum Tensile Strength, lb. per sq. in.	Minimum Elongation in 2 in., per cent
A	18 000	1
B	18 000	..
C	19 000	..
D	25 000	1
E	18 000	8

to conform to the following:

Alloy	Minimum Tensile Strength, lb. per sq. in.	Minimum Elongation in 2 in., per cent
A	18 000	8
B	16 000	3.5
C	18 000	..
D	18 000	..

Committee B-2 recommends that these revisions be accepted for publication as tentative.

A statement covering the wrought light aluminum alloys has been prepared and is appended to this report under the title of "High Strength Light Alloys." A similar statement covering magnesium alloys is in preparation.

SUB-COMMITTEE X ON METHODS OF TESTING

The sub-committee reported that it had prepared a list showing all physical tests mentioned or used in present standard or tentative standard specifications of the Society for non-ferrous metals. This list had been sent to each sub-committee chairman with the request that he make suggestions for Sub-Committee X covering new methods of tests required by his sub-committee or revisions of the present ones. The returns have indicated that the present methods of test appear to be sufficient and satisfactory as far as the sub-committees are concerned.

The chairman of the sub-committee has served as liaison between Committee B-2 and Committee E-1 on Methods of Testing and it is believed that reconciliation has been effected between the tentative specifications for hardness and compression testing at present being drawn up by Committee E-1 and those methods in use under present Committee B-2 specifications. This has been arranged through cooperation with Sub-Committee III and Sub-Committee IV.

The suggestion was made that the bend test should be standardized for non-ferrous metals.

There was some discussion of the manner in which Sub-Committee X should function and of altering its organization in such a way as to make it more flexible and adapted to the peculiar type of liaison and cooperative work which it will probably have to undertake.

REPORT OF SUB-COMMITTEE XI ON LEAD PIPE

The chairman has prepared a report covering methods in commercial use today for designating lead pipe sizes, which appears in Appendix III to this report.

REPORT OF SUB-COMMITTEE XII ON METALLIC FLUXES AND DEOXIDIZERS

The sub-committee presents three new Tentative Specifications for Phospher Tin, Phosphor Copper, and Silicon Copper, which are appended hereto.[1]

At the February meeting of the American Institute of Mining and Metallurgical Engineers there was held a "round-table" discussion of fluxes and deoxidizers.

In the light of this discussion the following action was tentatively decided upon. First, all members of the committee will submit the names of manufacturers of fluxes known to them, together with information regarding the brand name, and general characteristics of the fluxes furnished by such companies. A letter will then be sent to the producers of the fluxes, inviting such companies to submit samples of the fluxes, together with descriptive matter, and recommendations as to their use, to the committee for its consideration. An attempt will be made to obtain chemical analyses by dividing the samples among the members of the committee and also by sending them to other parties who may volunteer to assist in this work.

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[1] See pp. 779-784.—ED.

After completion of analyses, it is proposed to classify the fluxes and deoxidizing agents by analyses into two general classes, namely, those which are dependent for their action on some well-known deoxidizing agent, such as phosphorus, silicon, manganese or aluminum, and those which are dependent for their action on a complex mixture of a number of agents, or have no apparent potency. Following this classification, such fluxes for which manufacturers claim extraordinary properties, due to peculiar mixtures, such as treatment with boron gas, etc., will be studied in comparison with the same mixtures, minus the peculiar treatment, and the difference in results noted.

Mr. Gillett has offered the cooperation of the Bureau of Standards in making many of these comparative tests.

It is realized that the program laid down by the sub-committee is rather comprehensive, and will require the cooperation of all of its members and probably the assistance of others not members of the committee, but it is believed that the results which will be obtained from such a study will be well worth the effort.

The above reports were all accepted and approved at the meeting of Committee B-2 on March 13. The recommendations contained therein were adopted as the recommendations of Committee B-2.

The analysis of the letter ballot of the committee is as follows:

Item	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS IN STANDARDS			
1. Electrolytic Copper (B 4 – 13)	35	0	60
2. Lake Copper (B 5 – 13)	35	0	60
3. Brass Pipe (B 43 – 23)	31	0	64
4. Copper Pipe (B 42 – 23)	32	0	63
5. Manganese-Bronze Ingots (B 7 – 14)	29	1	65
6. Aluminum Casting Alloys (B 26 – 21)	29	0	66
II. PROPOSED NEW TENTATIVE STANDARDS			
7. Seamless Muntz Metal Condenser Tubes	27	0	68
8. 70-30 Brass Condenser Tubes	30	0	65
9. Manganese-Bronze Sand Castings	30	1	64
10. Phosphor Copper	33	1	61
11. Phosphor Tin	34	0	61
12. Silicon Copper	33	0	60
III. TENTATIVE REVISIONS ADVANCED TO STANDARD			
13. Methods of Chemical Analysis of Pig Lead (B 35 – 23 T)	39	0	66
IV. TENTATIVE STANDARD ADVANCED TO STANDARD.			
14. Specifications fnr Admiralty Condenser Tubes (B 44 – 23 T)	25	3	47

This report has been submitted to letter ballot of the committee, which consists of 95 members, of whom 46 have voted affirmatively, none negatively, and 49 have refrained from voting.

Respectfully submitted on behalf of the committee,

WILLIAM CAMPBELL,
Chairman.

P. D. MERICA,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Light Aluminum Casting Alloys, referred to in this report, were accepted for publication as new tentative specifications and appear on page 785. The proposed revisions of the Standard Specifications for Electrolytic Copper and for Lake Copper were accepted for publication as tentative and appear on pages 1118-1119. The proposed revisions of the Standard Specifications for Brass Pipe and for Copper Pipe, recommended in this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Methods of Chemical Analysis of Pig Lead, proposed in 1923, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Specifications for Admiralty Condenser Tubes, amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed Tentative Specifications for Manganese-Bronze Ingots for Sand Castings were accepted for publication as tentative and the Standard Specifications for Manganese-Bronze Ingots for Sand Castings were withdrawn, as recommended in this report. The tentative specifications appear on page 789. The proposed Tentative Specifications for Seamless Muntz Metal Condenser Tubes, for 70-30 Brass Condenser Tubes, for Manganese-Bronze Sand Castings, for Phosphor Copper, for Phosphor Tin and for Silicon Copper, referred to in this report, were accepted for publication as tentative and appear on pages 779-784 and 791-801.

APPENDIX I

THE EFFECT OF IMPURITIES ON THE COMPRESSIVE STRENGTH AND BRINELL HARDNESS OF BABBITT METAL AT NORMAL AND ELEVATED TEMPERATURES[1]

By John R. Freeman, Jr., and Paul F. Brandt[2]

Introduction

The Bureau of Standards was requested by Sub-Committee IV on White Metals of Committee B-2 on Non-Ferrous Metals and Alloys of the Society to continue its studies of the physical properties of white metal bearing alloys. In a previous report[3] the physical properties of the present tentative A.S.T.M. White Metal Bearing Alloys[4] were presented. It was requested that the effect of the common impurities in these alloys on their compressive strength and Brinell hardness at normal and elevated temperatures be determined, the same methods being used as in previous work.[5]

Scope of Work

It was first believed advisable to determine the effect of all the impurities on the twelve tentative standard alloys. This program, however, would have involved a very extensive amount of testing and therefore the work was confined to two representative alloys, a typical lead-base and a typical tin-base alloy. The impurities, the effects of which were to be studied, were zinc, arsenic, and copper in the lead-base alloys and zinc and arsenic in the tin-base alloys.

Preparation of Alloys

The alloys were all prepared from commercially pure metals. The representative alloy was first prepared free from impurities and the impurities added and test specimens obtained in the following

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[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Physicist and Laboratory Assistant, respectively, U. S. Bureau of Standards, Washington, D. C.

[3] John R. Freeman, Jr., "The Physical Properties of the A.S.T.M. Tentative Standard White Metal Bearing Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 207 (1922).

[4] Tentative Specifications for White Metal Bearing Alloys (Serial Designation: B 23 - 18 T).

[5] *Loc. cit.* Also Bureau of Standards *Technologic Paper No. 188.*

TABLE I.—COMPOSITION OF ALLOYS.[1]

All values are per cent

Alloy	Tin	Lead	Antimony	Arsenic	Zinc	Copper	Iron
No. 1	9.4	74.14[a]	16.2	0.01	....	less than 0.15	less than 0.10
No. 2	9.4[b]	74.14[b]	16.2[b]	0.14	....	less than 0.15[b]	less than 0.10[b]
No. 3	9.4[b]	74.14[b]	16.2[b]	0.40	....	less than 0.15[b]	less than 0.10[b]
No. 4	9.3	73.59[a]	16.4	0.46	....	less than 0.15[b]	less than 0.10[b]
No. 5	9.3	73.8	16.7	less than 0.02	....	trace	less than 0.06
No. 6	9.3[b]	73.8[b]	16.7[b]	less than 0.02[b]	....	0.55	less than 0.06[b]
No. 7	9.3[b]	73.8[b]	16.7[b]	less than 0.02[b]	....	1.0	less than 0.06[b]
No. 8	10.0	73.5	15.3	less than 0.02	....	1.1	less than 0.06
No. 9	90.29[a]	....	4.6	0.06	....	5.0	less than 0.05
No. 10	90.29[b]	....	4.6[b]	0.41	....	5.0[b]	less than 0.05[b]
No. 11	90.29[b]	....	4.6	0.51	....	5.0[b]	less than 0.05[b]
No. 12	87.95[a]	....	4.5	3.00	....	4.5	less than 0.05
No. 13	8.6	74.8	16.1	0.02	n. d.[c]	0.10	0.3
No. 14	8.6[b]	74.8[b]	16.1[b]	0.02[b]	0.74	0.10[b]	0.3[b]
No. 15	8.8	73.6	15.6	0.02	1.4	0.10	0.3
No. 16	90.4[a]	0.03	4.6	0.10	n. d.	4.6	less than 0.06
No. 17	90.4[b]	0.03[b]	4.6[b]	0.10[b]	0.42	4.6[b]	less than 0.06[b]
No. 18	90.4[b]	0.03[b]	4.6[b]	0.10[b]	0.91	4.6[b]	less than 0.06[b]
No. 19	89.4	0.03	4.6	0.10	1.3	4.4	less than 0.06

[1] All chemical analyses were made by J. A. Scherrer of the Bureau of Standards.

[a] By difference.

[b] Assumed value taken from analysis of "Base" alloy.

[c] n. d. = not detected.

TABLE II.—BRINELL HARDNESS AND YIELD POINT.

Alloy	Impurity, per cent		Brinell Hardness 500 kg. Load, 10-mm. Ball		Yield Point, lb. per sq. in.	
			20° C.	100° C.	20° C.	100° C.
LEAD-BASE ALLOYS						
No. 1	Arsenic	0.01	22.0	11.5	3950	1800
No. 2	Arsenic	0.14	22.5	12.0	4100	2350
No. 3	Arsenic	0.40	23.0	12.0	3900	2050
No. 4	Arsenic	0.46	23.5	13.0	4550	1800
No. 5	Copper	trace	23.5	12.0	4000	2250
No. 6	Copper	0.55	25.5	13.5	4100	2000
No. 7	Copper	1.0	25.0	13.0	4050	2200
No. 8	Copper	1.1	24.5	13.0	4150	2250
No. 13	Zinc	n. d.[a]	22.5	11.0	3850	1900
No. 14	Zinc	0.74	25.0	12.5	4200	2600
No. 15	Zinc	1.4	25.0	12.5	4100	2300
TIN-BASE ALLOYS						
No. 9	Arsenic	0.06	20.0	9.5	5000	2950
No. 10	Arsenic	0.41	24.5	12.0	6050	3450
No. 11	Arsenic	0.51	23.5	12.0	5600	3300
No. 12	Arsenic	3.00	....	....	5500	3200
No. 16	Zinc	n. d.	21.0	11.0	5200	2400
No. 17	Zinc	0.42	19.0	10.5	5300	3550
No. 18	Zinc	0.91	18.5	10.5	5300	3100
No. 19	Zinc	1.3	19.0	10.0	5350	3350

[a] n. d. = not detected.

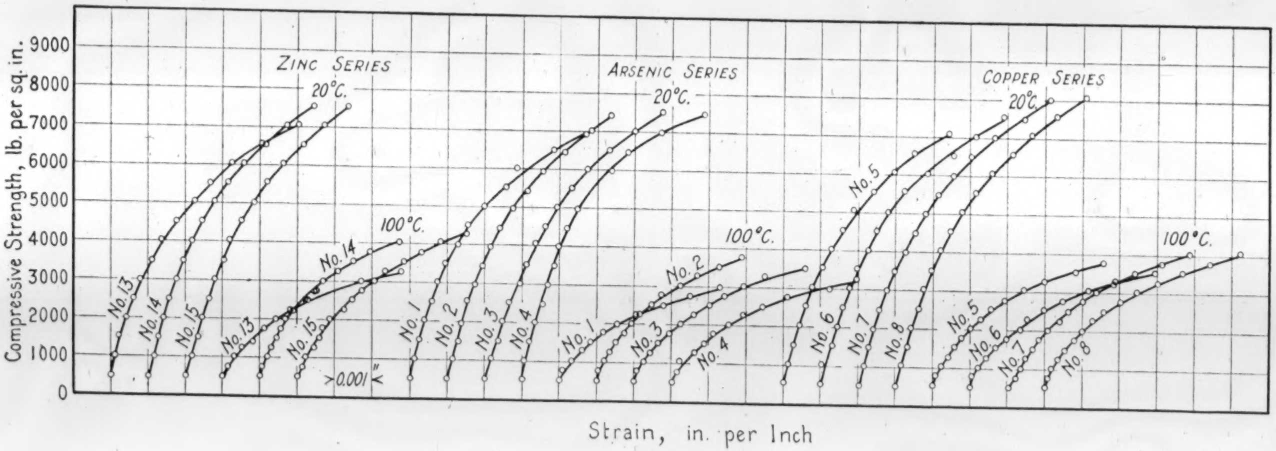

FIG. 1.—Average Stress-Strain Curves for Lead-Base Alloys.

manner. A quantity of the alloy sufficient to cast all the test specimens required for any one series of impurity content was melted. Specimens representing the pure alloy were chill cast, the same methods being used as reported in the previous work mentioned above. A calculated weight of impurity to give a desired impurity content was then added to the bath of molten metal and stirred in. Test specimens were then poured which represented an alloy with a definite desired impurity content. A further addition of impurity was then made to the original bath of metal, thus increasing the impurity content, and test specimens poured. This cycle of impurity additions and pouring was repeated until the desired number of impurity additions had been obtained. Care was taken not to overheat the metal and to pour always at the same temperature. By casting a series in the above manner the difference in composition was readily confined to the impurity additions.

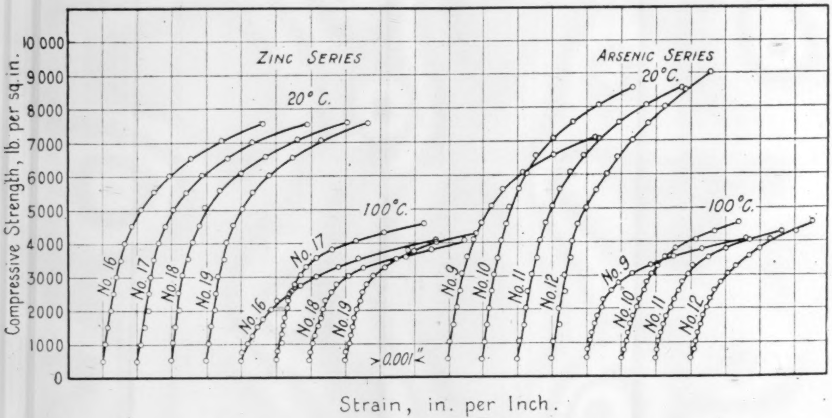

FIG. 2.—Average Stress-Strain Curves for Tin-Base Alloys.

The compression test specimens were cylinders $1\frac{1}{2}$ in. high by $\frac{1}{2}$ in. in diameter.

The compositions of all alloys tested are given in Table I.

TESTS OF ALLOYS

The apparatus (testing machine, compressometer, heating bath, etc.) used in this work was the same as that used in the previous investigations at the Bureau.[1] At least two compression tests were made for each impurity addition and temperature of test. The average of three Brinell-ball impressions made on each specimen was recorded for the Brinell hardness. Two compression tests and Brinell hardness determinations were made on all compositions at normal room temperature (approximately 20° C.) and at 100° C.

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[1] *Loc. cit.*

The yield point was arbitrarily taken as a reduction in length of 0.125 per cent measured over a gage length of one inch (0.00125 in.) from an initial load of 500 lb. per sq. in. This conforms with practice adopted in the previous publication by one of the authors above referred to.

The results of all tests are incorporated in Table II, and the average stress-strain curves for each alloy are given in Figs. 1 and 2.

DISCUSSION OF RESULTS

A comparison of the Brinell hardness data and stress-strain curves for the lead-base alloys, given in Table II and Fig. 1, indicates that additions of zinc, arsenic and copper to lead-base alloys cause, at normal and elevated temperatures, a small but noticeable increase in the hardness of the alloy and in its resistance to deformation, particularly at loads above the yield point. The effect of copper is not so noticeable as that of the zinc and arsenic.

In the tin-base alloys the presence of a low percentage of zinc does not appreciably affect the properties of the alloy at normal temperatures, although at 100° C. the resistance of the alloy to deformation appears to be increased. Arsenic increases the hardness and yield point of tin-base alloys at both normal and elevated temperatures.

APPENDIX II

HIGH-STRENGTH LIGHT ALLOYS

By E. Blough[1]

Introduction.—High-strength light alloys include several commercial alloys among which duralumin, manufactured in the United States by the Bausch Machine Tool Co., and 17S, 25S and 51S produced by the Aluminum Company of America are the most important. These alloys are susceptible of heat treatment in the wrought condition. It should, perhaps, be emphasized that these alloys are fundamentally wrought alloys; the properties are considerably lower in the cast condition. The statements which are made concerning their properties and heat treatment apply to material which has received sufficient working to destroy the cast structure. In fact, the properties after heat treatment are dependent up to a certain point upon the amount of work which is done on the metal. Consequently, thicker material does not, in general, develop the maximum properties which can be obtained from the alloy.

Each of the following fabricated forms is commercially available in some or all of the alloys mentioned: plate, sheet (both flat and coiled), bar, rod, wire, tubing (round, square, and oval), shapes (both rolled and extruded), stampings, forgings, rivets and automatic screw machine products. These alloys are supplied in several tempers and duralumin in at least two grades and 17S in three grades, produced by modifying the composition. The temper is determined by the condition as regards heat treatment. When subject to mechanical working, the alloys strain harden. If the alloy was initially in the cast or annealed state the resulting temper is designated as "hard" or "hard wrought"; the strength and hardness are fairly high and the elongation is quite low. On heating the alloys to suitable temperatures and cooling they are annealed and the resulting temper is designated as the "annealed" temper. The properties after annealing are independent of the condition of the material prior to heating, that is, whether "hard," "heat treated," or "strain hardened after heat treatment," etc.

The above statements concerning temper are applicable to all of the alloys mentioned. In discussing the heat-treated temper, it is necessary to discriminate between duralumin and 17S on the one hand and 25S on the other. If any of these alloys be heated to a suitable temperature, then quenched, the strength and hardness are materially increased over the values normally possessed by the materials in the hard-wrought temper and the elongation is likewise very greatly increased. As in the case of the annealing operation, the initial temper of the metal is of no consequence.

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On standing at ordinary temperatures, 17S and duralumin undergo a further increase in strength and hardness with little or no change in elongation, any change which may occur being, in general, a slight increase. This effect, commonly referred to as aging, is at first very rapid but proceeds at a gradually decreasing rate over a considerable period of time. The greater portion of the increase is effected within a few hours. Heating the alloy to the temperature of boiling water accelerates somewhat the initial rate of aging but has little if any effect on the properties which result after several hours.

The alloys 25S and 51S do not undergo this spontaneous aging at ordinary temperatures. To bring about the further increase in tensile strength and hardness it is necessary to hold them at a temperature well above 100° C. (212° F.) for several hours. Both of these alloys are covered by patents owned by the Aluminum Company of America. They are, however, supplied also in the heat-treated and aged condition, in which case no further heat treatment is required.

All of the alloys of this class are strain hardened by mechanical work (rolling, drawing, forging, etc.), the rate of hardening depending upon the initial strength or hardness of the alloy. They are, therefore, susceptible of difficult forming operations when in the annealed temper. Even in the fully heat-treated and aged condition the alloys may be fabricated successfully provided the working which is required is not too severe. In the condition in which the alloys come from the quenching bath, the properties are intermediate between those of the annealed and the fully heat-treated and aged condition and the alloys will withstand fabricating operations only slightly less severe than those which can be accomplished with annealed materials.

In order to realize this greater workability in the case of duralumin and 17S it is necessary to remove the material promptly from the quenching medium and complete its fabrication at once. The permissible time interval will vary with the severity of the operation and other conditions from one-half hour to two or three hours. The normal aging effect will then be superposed upon the strain hardening which has been produced by working the metal.

In the case of 25S and 51S the properties of the material as quenched are permanent until the second heat treatment or "artificial aging" is performed. The forming may, therefore, be accomplished without regard to the time of quenching and the fabricated articles may then be artificially aged.

In some cases where maximum strength is not required it is possible to obtain the desired result by using a modified grade of duralumin or 17S which will give greater ductility and obviate the necessity of resorting to heat treatment immediately before fabrication or to the use of the alloy in the annealed temper. Certain very difficult operations may even require the use of the modified grade in the annealed temper for their successful accomplishment.

It should be stated, however, that these alloys are primarily intended to be used in the heat-treated temper and to resort to a modified grade or a softer temper is to sacrifice a part of their utility. Many times, fabricating difficulties may be overcome by a minor modification of design or tooling, and advantage should be taken of the manufacturer's experience before resorting to softer material. The use of a reasonable radius instead of a sharp bend has solved many of the difficulties which have been experienced by users of these alloys.

Composition.—Most government specifications for commodities fabricated from 17S or duralumin contain the composition limits in the following table:

Copper	3.5 to 4.5 per cent
Manganese	0.4 to 1.0 "
Magnesium	0.3 to 0.75 "
Aluminum (minimum)	92.00 "

Small amounts of certain other elements may be added on the basis of these limits and such additions have been or are made by the different manufacturers for certain specific purposes. Calcium and chromium are two of the noteworthy examples.

There has been some disposition to restrict the permissible iron and silicon content of these alloys in some of the earlier specifications but, due to the lack of any evidence that these elements are objectionable in the amounts which may be present and still permit the specific requirements to be met, these limits are now generally omitted.

The modified grades contain lower percentages of one or more of the alloying elements copper, manganese and magnesium.

The alloys 25S and 51S are of recent development and specifications have not as yet been set for them. The alloy 25S differs from 17S and duralumin in the following respects: it contains no added magnesium and has a somewhat higher copper content together with some added silicon in excess of the amount which is ordinarily present in the commercial aluminum which is used in its manufacture. The alloy 51S is made by adding magnesium and silicon in relatively small amounts to commercial aluminum. As stated previously, both 25S and 51S are proprietary alloys, the patents which cover their compositions and their methods of heat treatment being owned by the Aluminum Company of America. While it is not possible to set specification limits for 25S and 51S as was stated above, the manufacturer's tentative operating limits are as follows:

ALLOY 25S

Copper	3.9 to 5.0 per cent
Manganese	0.5 to 1.1 " "
Silicon	0.5 to 1.1 " "
Aluminum (minimum)	92 per cent

ALLOY 51S

Magnesium	0.45 to 0.80 per cent
Silicon	0.60 to 1.2 " "
Aluminum (minimum)	96.5 per cent

Density.—The density of duralumin, 17S and 25S are very nearly the same. The actual figure depends upon the composition of the sample which is tested. In general the specific gravity lies between 2.79 and 2.82. Government specifications on which duralumin and 17S are supplied require that the specific gravity shall not exceed 2.85.

The elements used in the manufacture of 51S are less dense than aluminum, but due to the small total addition the density of the resulting alloy is only slightly less than that of the aluminum itself. The specific gravity is very nearly 2.69.

Stated differently, duralumin, 17S and 25S weigh approximately 175 lb. per cu. ft. and 51S weighs approximately 168 lb. per cu. ft.

Mechanical Properties.—There are certain mechanical properties which are characteristic of each of these alloys in the various tempers. There are, however, various factors which make it impossible for all fabricated forms to show these characteristic properties in all sizes. One of these is the amount of working which the material receives in the course of its manufacture. As stated above, if the metal is not thoroughly worked the properties will fall short of those which may be obtained in the particular alloy. This influence becomes apparent in sheet heavier than $\frac{1}{8}$ in. in thickness and in bars larger than $\frac{3}{4}$ in. in diameter and in heavy forgings, and manifests itself by a lower tensile strength and elongation. As the amount of rolling, drawing, etc., which is required to produce the material decreases, the effect becomes more pronounced and in very heavy material the tensile strength may be affected by as much as 10,000 lb. per sq. in. and the elongation in 2 in., by 8 to 10 per cent.

Another factor which affects the tensile properties is the form of the test specimens. This is determined by the character of the material to be tested and has its most pronounced effect on the elongation. This effect is obviated in rod and bar by choosing a gage length for the measurement of elongation, which is proportional to the thickness of the test specimen rather than the customary 2 in. In the case of thin sheet, however, the elongation as measured in 2 in. will be some few per cent less than the normal value.

With the qualifying statements which have been mentioned the following properties are characteristic of the various alloys. Due to the facts stated above, these values cannot be considered as specification values for all products.

17S, 25S, AND DURALUMIN ALLOYS

	ANNEALED TEMPER	HEAT TREATED TEMPER
Tensile strength, lb. per sq. in.	25 000 to 35 000	55 000 to 65 000
Yield point, lb. per sq. in.	....	30 000 to 40 000
Elongation in 2 in., per cent	12 to 22	18 to 25
Brinell hardness (500 kg., 10-mm. ball)	45 to 55	90 to 110

The properties of the hard wrought temper vary quite widely depending upon the amount of work which is done on the metal subsequent to annealing. The alloys in the heat-treated temper may be strain hardened by working cold, the tensile strength, yield point and hardness are increased appreciably but at the expense of a very considerable decrease in elongation.

The modified grades of duralumin and alloy 17S possess tensile strengths of from 5,000 to 10,000 or more pounds per square inch less than the value which is shown by the normal compositions and elongations some few per cent higher.

As stated previously alloy 25S is also available in the temper as quenched, that is, without artificial aging. In this condition the properties are approximately as follows:

ALLOY 25S, AS QUENCHED (UNAGED)

Tensile strength	43 000 to 53 000 lb. per sq. in.
Elongation in 2 in.	18 to 25 per cent

Subject to the same limitations discussed above, the properties of 51S are as follows:

ALLOY 51S

	ANNEALED TEMPER	HEAT TREATED TEMPER	AS QUENCHED (UNAGED)
Tensile strength, lb. per sq. in	14 000 to 17 000	45 000 to 50 000	30 000 to 40 000
Yield point, lb. per sq. in.....	....	25 000 to 35 000	....
Elongation in 2 in., per cent..	20 to 32	10 to 15	20 to 30
Brinell hardness............	....	85 to 100	....

In giving figures for the mechanical properties for alloys 51S and for 25S, it should be borne in mind that these alloys have only recently been placed in commercial production. It is therefore impracticable to give data which will be suitable for specification purposes. The data which are given represent quite a large number of tests on varied products and show the general physical characteristics of the alloys.

Chemical Properties.—These alloys are all quite resistant to ordinary atmospheric corrosion. Duralumin and alloy 17S have been used very extensively in seaplane construction and have withstood the severe conditions imposed by this use with entire satisfaction. The greatest resistance is shown by the heat-treated material.

Exact statements as to the relative merits of the various alloys as regards this property can be made only after extended trial and actual use. Data obtained from laboratory experimentation and from the performance data which are available at present, indicate that the newer alloys will also prove entirely satisfactory under all conditions where they may be called upon to serve.

Machining Properties.—These alloys may all be machined. The tools which are used differ from those commonly used for steel and brass. The manufacturers should be consulted in connection with machining problems, in order that the user may have the advantage of the experience which has been gained in handling these materials.

Annealing.—The annealing conditions are practically the same for all of the alloys which have been discussed. The material should be heated to a temperature between 650 and 700° F., 345 and 370° C., and allowed to cool. It is quite essential that these temperature limits be strictly observed and that the metal shall have actually been heated to within this range. If heated too high, effects similar to heat treatment, though very much less in actual amount, are produced and if the temperature is too low the metal will not be softened.

Heat Treatment.—The heat treatment of duralumin and of alloy 17S is quite simple and consists in raising the temperature of the metal within the range 930 to 950° F., 500 to 510° C., and quenching. The safe treatment range is actually somewhat greater than the practical working range which is given above but because of the difficulties of close temperature control at these temperatures it is safer to aim for the limits which are given above. The quenching medium most commonly used is water at or near the boiling point, although cold water may be used.

In both the heat treating and the annealing operations rather careful temperature control is required and it is the metal temperature which must be considered. This point is emphasized because of the fact that considerable differences may exist between the temperature at the center of a load and the furnace temperature. A well-stirred nitrate bath has certain advantages over an air furnace, although under proper control the latter is entirely satisfactory.

Users will find the manufacturers of these alloys very glad to give advice on questions concerning design and operation of proper heat treating equipment.

The heat treating temperature range for alloys 25S and 51S and the optimum aging conditions are supplied to the trade together with the license for their use by the Aluminum Company of America.

APPENDIX III

COMMERCIAL PRACTICE RELATING TO SIZES OF LEAD PIPE

By W. A. Cowan[1]

It has been a custom of very long standing to specify thicknesses of lead pipe by a series of letters corresponding to certain weights per linear foot for each size of different caliber. The series of letters adopted in the East and West, however, differ from each other. The western schedule is used in Pittsburgh, Cleveland, Cincinnati and in the West, while the eastern schedule is used only east of these places.

The two series are as follows:

East	West
E	AQ
D	XL
C	L
B	M
A	S
AA	XS
AAA	XXS

The letters in the eastern series obviously have no descriptive significance, simply being the first letters of the alphabet. The letters in the western series are probably abbreviations of the following terms, respectively: Aqueduct, extra light, light, medium, strong, extra strong, double extra strong.

In each series the first letter as given designates the lightest weight or thinnest walled pipe and the last stands for the heaviest or thickest, as ordinarily manufactured, for each common size as to caliber. Lists of sizes and weights usually begin with $\frac{3}{8}$ in. inside diameter, anything smaller than this being described as lead tubing. The lists, for lead pipe supplied in coils, include pipe up to 2 in. in inside diameter. The series of letters are used for larger sizes, in some cases up to 6 in. caliber, the pipe being furnished in straight lengths instead of coils.

The larger sizes, in the smaller weights, are in some cases designated "waste" pipe instead of "aqueduct" or "light."

The weights per foot of the pipe corresponding to the letters of the series, for various calibers, have apparently been established in an arbitrary manner. The eastern and western series are not in this respect entirely uniform; although pipe designated as "B" in the east is in most cases of the same weight as pipe "M" of the western schedule, and the other letters generally correspond—for instance, as "AA" to "XS." While there is general agreement in practice, it is probable that lists of different manufacturers or users may vary to some extent.

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As should be expected, the weight per foot of pipe, corresponding to any one of the different letters, increases respectively with increase in the caliber. For instance, "B" pipe of $\frac{3}{8}$-in. caliber weighs 1 lb. per ft., while "B" pipe of $1\frac{1}{2}$-in. caliber weighs 5 lb. per ft. However, one might expect that the series of letters had been based either on the same wall thickness or the same strength in resistance to bursting, or with some other basis of uniformity, but this is not, in fact, the case. With pipe of $\frac{3}{8}$-in. caliber, the wall thickness is 0.128 in., whereas with $1\frac{1}{2}$-in. caliber it is 0.191 in.; while the strength of the former is nearly three times as great as that of the latter.

Although it is quite apparent that pipes of the same letter in the various calibers do differ in strength, it may be that it was originally supposed that they more nearly correspond. This is indicated by a tabulation as shown in Table I taken from Kent's *Mechanical Engineers Handbook*, under the heading "Weight of Lead Pipe Which Should be Used for a Given Head of Water." This table is found in various catalogues. In it a uniform pressure is indicated as suitable for lead pipe of the same letter for all of the different calibers. However, as calculated by formula on the basis of tensile strength of the lead, the bursting strengths of the pipes of various bores for the same letter are not equivalent. It is at least the case in the table referred to that the greater factor of safety is allowed for the smaller bore pipe, whereas it would be reasonable to allow the greater factor of safety for pipe of the larger inside diameters. Tables for strength of iron pipe are customarily given in the latter way.

In commercial practice, lead pipe is specified by letter, inside diameter and corresponding weight per linear foot, without in general any statement being made as to actual thickness of wall. In fact, in manufacturing departments the dies through which the lead pipe is extruded and which regulate its outside diameter are simply marked with the letter, or with pounds per foot for each of the different calibers. The cores which are used to regulate the inside diameters are selected by actual measurement in inches. The dies were, of course, originally made from calculations of thickness required to give the desired weight per foot. However, it is not known on what data such calculations were made, and the diameter of the dies is not exactly the same as the outside of the finished pipe, since, in extruding, some shrinkage takes place in the metal after it has passed through the die.

Various tables have been prepared giving the outside diameters and thicknesses corresponding to weights per linear foot of lead pipe. These are, of course, based on specific gravity of the lead. However, the tabulations as calculated by different individuals may vary slightly, depending on the figure chosen for specific gravity of lead and for the weight per cubic foot of water, that is, depending on whether the latter is taken at 4° C. or at room temperature.

Formulas for deriving thickness from weight per linear foot are as follows:

R = outside radius in inches

r = inside radius in inches

W = weight in pounds per linear foot of lead pipe

62.355 = weight in pounds of 1 cubic foot of water at 62° F. (16.6° C.)

11.37 = specific gravity of lead

$$W = 12\pi\ (R^2 - r^2)\ \frac{62.355 \text{ x } 11.37}{1728}$$

$$W = 15.4675\ (R^2 - r^2)$$

$$R = \sqrt{r^2 + \frac{W}{15.4675}}$$

Thickness = $R - r$

Outside diameter = $2R$

Some of these tabulations are appended, as follows:

1. National Lead Co., Laboratory Bulletin.
2. Hoyt Metal Co., Catalogue of Products of Rolling Mill and Pipe Departments.
3. Kent's Mechanical Engineers Handbook, giving tables from United Lead Co., 1920.
4. Colwell Lead Co. (old).

In the tabulation of the National Lead Co. Laboratory Bulletin there are given two columns representing, respectively, "Bursting Pressure" and "Safe Working Pressure." These are calculated from the formula $P = \frac{2\,S\,T}{D}$

where P = pressure in pounds per square inch

S = tensile strength of lead in pounds per square inch

T = thickness, in inches

D = inside diameter, in inches

In the calculation of this table, the ultimate tensile strength of lead was taken as 2300 lb. per sq. in. An arbitrary factor of safety of 8 was used for obtaining the figure given as safe working pressure. In the text accompanying the tabulation it is stated that the factor of safety used is not sufficiently great for temperatures above the ordinary. For instance, in determining safe working

TABLE I.—LEAD AND TIN-LINED LEAD PIPE.

(United Lead Co., New York, 1920)

Inside Diameter, in.	Letter	Weight per Foot	Thickness, 1/100 in.	Inside Diameter, in.	Letter	Weight per Foot	Thickness, 1/100 in.	Inside Diameter, in.	Letter	Weight per Foot	Thickness, 1/100 in.
⅜	D	10 oz.	9	⅝	AA	2¾ lb.	21	1¼	AA	5¾ lb.	25
	C	12 "	10		AAA	3½ "	26		AAA	6¾ "	28
	B	1 lb.	13								
	A	1¼ "	15	¾	E	1 "	8	1½	E	3 "	12
	AA	1½ "	17		D	1¼ "	9		D	3½ "	14
	AAA	1¾ "	20		C	1¾ "	13		C	4¼ "	16
					Special	2 "	14		B	5 "	19
7/16	....	13 oz.	10		B	2¼ "	16		A	6½ "	24
	....	1 lb.	12		A	3 "	20		AA	7½ "	27
					AA	3½ "	23		AAA	8½ "	30
½	E	9 oz.	6		AAA	4¾ "	29				
	D	12 "	8					1¾	D	4 "	14
	C	1 lb.	11	1	E	1½ "	9		C	5 "	17
	B	1¼ "	13		D	2 "	12		B	6 "	20
	Special	1½ "	15		C	2½ "	14		A	7 "	23
	A	1¾ "	17		B	3¼ "	18		AA	8½ "	27
	AA	2 "	19		A	4 "	21		AAA	10 "	31
	Special	2½ "	22		AA	4¾ "	25				
	AAA	3 "	26		AAA	6 "	30	2	D	4¾ "	14
									C	6 "	18
⅝	E	¾ "	7	1¼	E	2 "	10		B	7 "	21
	D	1 "	9		D	2½ "	12		A	8 "	23
	C	1½ "	13		C	3 "	14		AA	9 "	26
	B	2 "	16		B	3¾ "	17		AAA	11¾ "	33
	A	2½ "	20		A	4¾ "	21				

TABLE II.—WEIGHT OF LEAD PIPE WHICH SHOULD BE USED FOR A GIVEN HEAD OF WATER.

(United Lead Co., New York, 1920)

Head or Number of Feet Fall	Pressure, lb. per sq. in.	Caliber and Weight per Foot						
		Letter	⅜ in.	½ in.	⅝ in.	¾ in.	1 in.	1¼ in.
30 ft.	13	D	10 oz.	¾ lb.	1 lb.	1¼ lb.	2 lb.	2½ lb.
50 "	22	C	12 "	1 "	1½ "	1¾ "	2½ "	3 "
75 "	32	B	1 lb.	1¼ "	2 "	2¼ "	3¼ "	3¾ "
100 "	44	A	1¼ "	1¾ "	2½ "	3 "	4 "	4¾ "
150 "	65	AA	1½ "	2 "	2¾ "	3½ "	4¾ "	5¾ "
200 "	87	AAA	1¾ "	3 "	3½ "	4¾ "	6 "	6¾ "

pressure for lead pipe to convey hot water, a factor of safety twice as great should be used. It is also stated that a greater factor of safety is required in case of variation in pressure, such as might be caused by water hammer. The tabulation, however, has been found practicable as a basis of recommendations of thickness in respect to constant pressure at ordinary temperature.

TABLE III.—WEIGHT OF LEAD PIPE ACCORDING TO COLWELL LEAD CO.

Caliber, in.	Letter	Weight per Foot		Thickness, in.	Fractional, Equivalent Thickness	Outside Diameter, in.
		Lb.	Oz.			
$\frac{3}{8}$....	AAA	1	12	0.183	$\frac{3}{16}$ S	0.74
	AA	1	8	0.173	$\frac{11}{64}$ F	0.72
	A	1	4	0.143	$\frac{9}{64}$ F	0.66
	B	1	0	0.128	$\frac{1}{8}$ F	0.63
	C	0	12	0.103	$\frac{7}{64}$ S	0.58
	D	0	10	0.088	$\frac{3}{32}$ S	0.55
	E	0	7	0.068	$\frac{1}{16}$ F	0.51
$\frac{7}{16}$...	B	1	0	0.111	$\frac{7}{64}$ F	0.66
	C	0	13	0.096	$\frac{3}{32}$ F	0.63
$\frac{1}{2}$....	AAA	3	0	0.255	$\frac{1}{4}$ F	1.01
	AA	2	0	0.185	$\frac{3}{16}$ S	0.87
	A	1	12	0.170	$\frac{11}{64}$ S	0.84
	B	1	4	0.130	$\frac{1}{8}$ F	0.76
	C	1	0	0.105	$\frac{7}{64}$ S	0.71
	D	0	12	0.085	$\frac{5}{64}$ F	0.67
	E	0	9	0.065	$\frac{1}{16}$ F	0.63
$\frac{5}{8}$....	AAA	3	8	0.253	$\frac{1}{4}$ F	1.13
	AA	2	12	0.213	$\frac{7}{32}$ S	1.05
	A	2	8	0.198	$\frac{13}{64}$ F	1.02
	B	2	0	0.167	$\frac{11}{64}$ S	0.96
	C	1	8	0.128	$\frac{1}{8}$ F	0.88
	D	1	0	0.088	$\frac{3}{32}$ S	0.80
	E	0	12	0.073	$\frac{5}{64}$ S	0.77
$\frac{3}{4}$....	AAA	4	12	0.280	$\frac{9}{32}$ F	1.31
	AA	3	8	0.230	$\frac{15}{64}$ S	1.21
	A	3	0	0.205	$\frac{13}{64}$ S	1.16
	B	2	4	0.160	$\frac{5}{32}$ F	1.07
	C	1	12	0.130	$\frac{1}{8}$ F	1.01
	D	1	4	0.095	$\frac{3}{32}$ F	0.94
	E	1	0	0.080	$\frac{5}{64}$ F	0.91
1.....	AAA	6	0	0.295	$\frac{19}{64}$ S	1.59
	AA	4	12	0.255	$\frac{1}{4}$ F	1.51
1....	A	4	0	0.210	$\frac{13}{64}$ F	1.42
	B	3	4	0.180	$\frac{11}{64}$ F	1.36
	C	2	8	0.140	$\frac{9}{64}$	1.28
	D	2	0	0.115	$\frac{7}{64}$ F	1.23
	E	1	8	0.085	$\frac{5}{64}$ F	1.17
$1\frac{1}{4}$...	AAA	6	12	0.285	$\frac{9}{32}$ F	1.82
	AA	5	12	0.250	$\frac{1}{4}$	1.75
	A	4	12	0.210	$\frac{13}{64}$ F	1.67
	B	3	12	0.170	$\frac{11}{64}$ S	1.59
	C	3	0	0.135	$\frac{9}{64}$ S	1.52
	D	2	8	0.125	$\frac{1}{8}$	1.50
	E	2	0	0.100	$\frac{3}{32}$ F	1.45
$1\frac{1}{2}$...	AAA	8	8	0.305	$\frac{19}{64}$ F	2.11
	AA	7	8	0.270	$\frac{17}{64}$ F	2.04
	A	6	8	0.230	$\frac{15}{64}$ S	1.96
	B	5	0	0.190	$\frac{3}{16}$ F	1.88
	C	4	4	0.160	$\frac{5}{32}$ F	1.82
	D	3	8	0.140	$\frac{9}{64}$	1.78
	E	3	0	0.125	$\frac{1}{8}$	1.75
$1\frac{3}{4}$...	AAA	10	0	0.335	$\frac{21}{64}$ F	2.42
	AA	8	8	0.255	$\frac{1}{4}$ F	2.26
	A	7	0	0.230	$\frac{15}{64}$ S	2.21
	B	6	0	0.200	$\frac{13}{64}$ S	2.15
	C	5	0	0.170	$\frac{11}{64}$ S	2.09
	D	4	0	0.140	$\frac{9}{64}$	2.03
	E	..	..	.....	.....	....
2....	AA A	11	12	0.295	$\frac{19}{64}$ S	2.59
	AA	9	0	0.255	$\frac{1}{4}$ F	2.51
	A	8	0	0.225	$\frac{7}{32}$ F	2.45
	B	7	0	0.205	$\frac{13}{64}$ F	2.41
	C	6	0	0.185	$\frac{3}{16}$ S	2.37
	D	4	12	0.130	$\frac{1}{8}$ F	2.26

In the method of finding bursting pressure by calculation from the tensile strength of the material, it must be considered that the load at ultimate strength will give continued deformation with time,

Table IV.—Weight and Dimensions of Lead Pipe According to Hoyt Metal Co.

Western Classification	Inside Diameter, in.	Outside Diameter, in.	Weight per Foot		Coils, ft.	Average, lb.	Reels, ft.	Average, lb.	Standard Lengths	
			Lb.	Oz.					Ft.	Lb.
Tubing	$\frac{5}{32}$	0.250	2	3	..	..	834	120	..	..
"	$\frac{1}{4}$	0.358	..	4	..	..	480	120	..	..
"	$\frac{1}{4}$	0.381	...	5	..	..	384	120	..	..
"	$\frac{1}{4}$	0.402	..	6	..	..	..	..	..	..
"	$\frac{1}{4}$	0.442	..	8	..	..	..	..	..	..
"	$\frac{1}{4}$	0.511	..	12	133	100	160	120	..	..
AQ	$\frac{3}{8}$	0.522	..	8	200	100	1200	600	..	..
XL	$\frac{3}{8}$	0.553	..	10	160	100	960	600	..	..
L	$\frac{3}{8}$	0.582	..	12	133	100	800	600	..	..
M	$\frac{3}{8}$	0.637	1	..	100	100	600	600	..	..
S	$\frac{3}{8}$	0.733	1	8	116	175	666	1000	..	..
XS	$\frac{3}{8}$	0.819	2	0	87	175	800	1000	..	..
XXS	$\frac{3}{8}$	0.896	2	8	70	175	400	1000	..	..
AQ	$\frac{1}{2}$	0.618	..	8	200	100	1200	600	..	..
XL	$\frac{1}{2}$	0.670	..	12	133	100	800	600	..	..
L	$\frac{1}{2}$	0.717	1	0	100	100	600	600	..	..
M	$\frac{1}{2}$	0.762	1	4	80	100	480	600	..	..
A	$\frac{1}{2}$	0.804	1	8	116	175	666	1000	..	..
S	$\frac{1}{2}$	0.845	1	12	100	175	571	1000	..	..
AA	$\frac{1}{2}$	0.883	2	0	87	175	500	1000	..	..
XS	$\frac{1}{2}$	0.955	2	8	70	175	400	1000	..	..
XXS	$\frac{1}{2}$	1.022	3	0	58	175	333	1000	..	..
AQ	$\frac{5}{8}$	0.767	..	12	133	100	800	600	..	..
XL	$\frac{5}{8}$	0.809	1	..	100	100	600	600	..	..
L	$\frac{5}{8}$	0.888	1	8	66	100	400	600	...	..
M	$\frac{5}{8}$	0.959	2	0	50	100	300	600	..	..
A	$\frac{5}{8}$	0.993	2	4	77	175	444	1000	..	..
S	$\frac{5}{8}$	1.026	2	8	70	175	400	1000	..	..
AA	$\frac{5}{8}$	1.058	2	12	63	175	400	1000	..	..
XS	$\frac{5}{8}$	1.089	3	0	58	175	333	1000	..	..
XXS	$\frac{5}{8}$	1.148	3	8	50	175	285	1000	..	..
AQ	$\frac{3}{4}$	0.891	..	14	142	125	685	600	..	..
XL	$\frac{3}{4}$	0.945	1	4	100	125	480	600	..	..
L	$\frac{3}{4}$	1.013	1	12	71	125	342	600	..	..
M	$\frac{3}{4}$	1.076	2	4	77	175	444	1000	..	..
A	$\frac{3}{4}$	1.107	2	8	70	175	400	1000	..	..
S	$\frac{3}{4}$	1.165	3	0	58	175	333	1000	..	..
XS	$\frac{3}{4}$	1.221	3	8	50	175	285	1000	..	..
XXS	$\frac{3}{4}$	1.274	4	0	50	200	250	1000	..	..
AQ	1	1.196	1	10	76	125	369	600	..	..
XL	1	1.237	2	0	62	125	300	600	..	..
L	1	1.276	2	6	52	125	252	600	..	..
M	1	1.364	3	4	53	175	307	1000	..	..
S	1	1.435	4	0	50	200	250	1000	..	..
XS	1	1.503	4	12	42	200	210	1000	..	..
XXS	1	1.609	6	0	33	200	166	1000	..	..
AQ	$1\frac{1}{4}$	1.446	2	0	70	140	300	600	..	..
XL	$1\frac{1}{4}$	1.491	2	8	56	140	240	600	..	..

TABLE IV.—WEIGHT AND DIMENSIONS OF LEAD PIPE ACCORDING TO HOYT METAL CO.—*Continued*

Western Classification	Inside Diameter, in.	Outside Diameter, in.	Weight per Foot		Coils, ft.	Average, lb.	Reels, ft.	Average, lb.	Standard Lengths	
			Lb.	Oz.					Ft.	Lb.
L	1¼	1.535	3	0	46	140	200	600	..	..
M	1¼	1.599	3	12	66	250	266	1000	..	..
S	1¼	1.680	4	12	52	250	210	1000	..	..
XS	1¼	1.775	6	0	41	250	166	1000	..	..
XXS	1¼	1.831	6	12	37	250	148	1000	..	..
AQ	1½	1.745	3	0	46	140	200	600	..	..
XL	1½	1.782	3	8	40	140	171	600	..	..
L	1½	1.837	4	4	32	140	141	600	..	..
M	1½	1.891	5	0	50	250	200	1000	..	..
S	1½	1.976	6	4	40	250	160	1000	..	..
XS	1½	2.090	8	0	31	250	125	1000	..	..
XXS	1½	2.153	9	0	27	250	111	1000	..	..
AQ	2	2.189	3	0	..	..	..	..	8	24
XL	2	2.249	4	0	..	..	..	..	8	32
L	2	2.307	5	0	..	..	..	..	8	40
M	2	2.392	6	8	38	250	..	..	..	..
S	2	2.447	7	8	33	250	..	..	..	..
XS	2	2.527	9	0	27	250	..	..	..	..
XXS	2	2.623	10	14	22	250	..	..	..	..
AQ	2½	2.703	4	0	..	..	..	..	8	32
XL	2½	2.752	5	0	..	..	..	..	8	40
L	2½	2.893	8	0	..	..	..	..	8	64
M	2½	3.027	11	0	..	..	..	..	8	88
S	2½	3.156	14	0	..	..	..	..	8	112
XS	2½	3.280	17	0	..	..	..	..	8	136
AQ	3	3.213	5	0	..	..	..	..	8	40
XL	3	3.244	5	12	..	..	..	..	8	46
L	3	3.374	9	0	..	..	..	..	8	72
M	3	3.504	12	6	..	..	..	..	8	99
S	3	3.639	16	0	..	..	..	..	8	128
XS	3	3.782	20	0	..	..	..	..	8	160
XL	3½	3.747	6	12	..	..	..	..	8	54
L	3½	3.843	9	8	..	..	..	..	8	76
M	3½	4.028	15	0	..	..	..	..	8	120
S	3½	4.142	18	0	..	..	..	..	8	148
XS	3½	4.252	22	0	..	..	..	..	8	176
Waste	4	4.1624	5	0	..	..	..	..	8	40
Waste	4	4.1941	6	0	..	..	..	..	8	48
Waste	4	4.2549	7	15	..	..	..	..	8	63½
L	4	4.3949	12	8	..	..	..	..	8	100
M	4	4.4992	16	0	..	..	..	..	8	128
S	4	4.6156	20	0	..	..	..	..	8	160
XS	4	4.7571	25	0	..	..	..	..	8	200
XXS	4	4.8946	30	0	..	..	..	..	8	240
Waste	5	5.1438	5	8	..	..	..	..	8	..
XS	5	5.5470	21	12	..	..	..	..	8	174
XXS	5	5.6182	24	12	..	..	..	..	8	198
XXXS	5	5.6944	28	0	..	..	..	..	8	224
XXXXS	5	5.7869	32	0	..	..	..	..	8	256
Waste	6	6.1365	6	4	..	..	..	..	8	50
XS	6	6.4680	22	0	..	..	..	..	8	176
XXS	6	6.6100	29	0	..	..	..	..	8	232
XXXS	6	7.0187	50	0	..	..	..	..	8	400

The factor of safety must be sufficiently great to reduce the safe working pressure to a point within the elastic limit—that is, where there will not occur deformation or swelling of the pipe with time. The factor of safety must also include all other possible variations, such as in pressure, temperature, wall thickness (affected by bends and by non-centering of core) accuracy of measurement and of tests, etc.

TABLE V.—PROPERTIES OF LEAD PIPE ACCORDING TO NATIONAL LEAD CO. LABORATORY BULLETIN

Tensile Strength of Lead, 2300 lb. per sq. in.; Factor of Safety, 8

Inside Diameter, in.	Letter	Outside Diameter, in.	Thickness, in.	Weight per Foot		Safe Working Pressure, lb. per sq. in.
				Lb.	Oz.	
$\frac{3}{8}$....	E	0.503	0.064	..	7	98
	D	0.549	0.087	..	10	133
	C	0.577	0.101	..	12	155
	B	0.631	0.128	1	..	196
	A	0.681	0.153	1	4	234
	AA	0.725	0.175	1	8	268
	AAA	0.769	0.197	1	12	302
$\frac{7}{16}$..	....	0.633	0.098	..	13	129
	....	0.670	0.116	1	..	152
$\frac{1}{2}$....	E	0.628	0.064	..	9	74
	D	0.666	0.083	..	12	95
	C	0.712	0.106	1	..	122
	B	0.756	0.128	1	4	147
	Special	0.798	0.149	1	8	171
	A	0.838	0.169	1	12	194
	AA	0.876	0.188	2	..	216
	Special	0.946	0.223	2	8	256
	AAA	1.012	0.256	3	..	294
$\frac{5}{8}$....	E	0.765	0.070	..	12	64
	D	0.803	0.089	1	..	82
	C	0.881	0.128	1	8	118
	B	0.953	0.164	2	..	151
	A	1.019	0.197	2	8	181
	AA	1.049	0.212	2	12	195
	AAA	1.137	0.256	3	8	236
$\frac{3}{4}$....	E	0.906	0.078	1	..	60
	D	0.940	0.095	1	4	73
	C	1.006	0.128	1	12	98
	Special	1.038	0.144	2	..	110
	B	1.068	0.159	2	4	122
	A	1.156	0.203	3	..	156
	AA	1.212	0.231	3	8	177
	AAA	1.336	0.293	4	12	225
1......	E	1.178	0.089	1	8	51
1..	D	1.232	0.116	2	..	67
	C	1.284	0.142	2	8	82
	B	1.356	0.178	3	4	102
	A	1.428	0.214	4	..	123
	AA	1.492	0.246	4	12	141
	AAA	1.596	0.298	6	..	171
$1\frac{1}{4}$	E	1.442	0.096	2	..	44
	D	1.486	0.118	2	8	54
	C	1.528	0.139	3	..	64
	B	1.592	0.171	3	12	79
	A	1.670	0.210	4	12	97
	AA	1.746	0.248	5	12	114
	AAA	1.818	0.284	6	12	131
$1\frac{1}{2}$	E	1.740	0.120	3	..	46
	D	1.776	0.138	3	8	53
	C	1.830	0.165	4	4	63
	B	1.882	0.191	5	..	73
	A	1.984	0.242	6	8	93
	AA	2.046	0.273	7	8	105
	Special	2.076	0.288	8	..	110
	AAA	2.108	0.304	8	8	117
$1\frac{3}{4}$	D	2.024	0.137	4	..	45
	C	2.085	0.168	5	..	55
	B	2.146	0.198	6	..	65
	Special	2.176	0.213	6	8	70
	A	2.206	0.228	7	..	75
	AA	2.292	0.271	8	8	89
	AAA	2.376	0.313	10	..	103
2..	D	2.284	0.142	4	12	41
	C	2.354	0.177	6	..	51
	B	2.410	0.205	7	..	59
	A	2.462	0.231	8	..	66
	AA	2.514	0.257	9	..	74
	AAA	2.652	0.326	11	12	94

A more direct way of testing to obtain data on which to base estimate of safe working pressures is by actual bursting tests on lengths of lead pipe, for instance, by subjecting them to hydraulic pressure. Such tests are carried out by applying increasing pressure at a certain rate or, in any case, the effective pressure is applied for only a short period of time. The results represent only the exact conditions under which the test was run and could be applied to different sizes and thickness of pipe only in a comparative way and by the use of a formula similar to that given above in connection with calculation from tensile strength. It would be difficult to interpret results or to standardize the test. In order to estimate safe working pressure from tests of this kind it is also necessary to use an arbitrary factor of safety. Besides including all other variables, this must be sufficiently great to reduce the allowed pressure to an amount which would effect no swelling or deformation of the pipe over an indefinite period of time. In this respect data can be more readily supplied by regular tensile tests, where the elastic limit can be approximately derived from the stress-strain diagram.

In either method of trying to arrive at a figure for safe working pressure, the factor of safety to be used is largely arbitrary. It is probable that it is taken principally in view of giving figures corresponding to what has been shown practicable by experience, under different conditions.

There is a formula given in Kent's Mechanical Engineers Handbook, p. 285, as quoted from Chadwick Lead Works, as follows:

> "To find the thickness of lead pipe required when the head of water is given:
>
> "Rule.—Multiply the head in feet by size of pipe wanted, expressed decimally, and divide by 750; the quotient will be the thickness required, in one-hundredths of an inch.
>
> "*Example.*—Required thickness of half-inch pipe for a head of 25 ft.:
> 25×0.50 divided by $750 = 0.016$ in."

This formula gives required thicknesses about twice as great as required for the same pressure in the Table (V) but much less than in Table (II).

A New York City ordinance requires "AA" pipe of $\frac{5}{8}$-in. or $\frac{3}{4}$-in. inside diameter to be installed for water supply service. The maximum stated pressure for this service is 86 lb. This complies fairly closely to the above formula, but with some added margin of safety.

It appears from all of the above that a requirement for safe working pressure is entirely a matter of judgment in choosing a proper factor of safety to cover the given conditions. Such judgment can be based on an exact technical method of testing only by referring back to tension tests of the material of which the pipe is made. It does not seem desirable or practicable to attempt to standardize a direct method of testing bursting pressure, and, as pointed out, a proper factor of safety to use in connection with such tests would still be a matter of guesswork or taken as corresponding to practical experience under a certain set of conditions.

The Society already has committees responsible for methods of testing strength of materials in which is included tensile strength of lead.

Two grades of lead are used for lead pipe. These should be based on the American Society for Testing Materials Standard Specifications for Pig Lead (B 29 – 23) covering common lead and chemical lead.

Specifications for lead pipe, besides giving requirements for safe working pressure and grade of lead to be used, in order to cover commercial practice, should include tabulations of weights and thicknesses corresponding to a standard series of letters for each different inside diameter.

While the present custom is not consistently systematic, the adoption of a specification for sizes on a reasonable basis involving conformity of the eastern and western schedule, would encounter the resistance of long-established commercial practice.

Standardization of sizes, unless in direct connection with methods of testing or with properties of materials, is not within the particular province of the Society.

DISCUSSION

Mr. Cowan.

MR. W. A. COWAN (*presented in written form*).—In Appendix I to the Report of Committee B-2, entitled "The Effect of Impurities on the Compressive Strength and Brinell Hardness of Babbitt Metal at Elevated Temperatures," by John R. Freeman, Jr., and Paul F. Brandt, the authors have presented the results of a carefully worked out investigation, which is very instructive and which will be of further value if the additional work requested by Sub-Committee IV on White Metals of Committee B-2, covering the effects of impurities on other properties, can be carried out.

In reporting yield point in compression tests made on the alloys investigated, the authors have used, according to custom, an arbitrarily taken amount of reduction in length of the test specimen, the amount adopted in this case being 0.125 per cent. A similar method of determining yield point is described in Section 18 of the proposed Tentative Methods of Tension Testing of Metallic Materials, being submitted by Committee E-1 on Methods of Testing.[1] The amount of deformation recommended therein is 0.01 in. over a gage length of 2 in., this being a deformation of 0.5 per cent.

In standardizing a method for determining yield point for both tension and compression tests, it is desirable that the method should be of universal application to all metals and alloys. This cannot be true with an arbitrarily taken fixed amount of deformation, either in percentage or in fractions of an inch. With some classes of metals or alloys, a certain constant deformation might be taken which would be suitable, but only because the corresponding point on the stress-strain diagram would lie where a yield point is reasonably indicated. This should be at a point where there is a marked yielding as shown by a deflection in the curve, and at some point beyond the actual proportional limit. The yield point should, of course, in no instance lie within the proportional limit. The suitability of a uniform amount of deformation for yield point as applied to the stress-strain diagram of various metals will depend upon the properties of the metals in question, and upon the resulting characteristics of the stress-strain curve. For instance, it is not probable that a yield point of a fixed amount of deformation would indicate similar physical characteristics of metals where the corresponding stress-strain diagrams have markedly different slopes, or where the metals differ widely in ductility. In the case of a metal with low modulus of elasticity, resulting in the

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[1] See p. 1081.—ED.

Mr. Cowan. slope of its stress-strain curve making a comparatively small angle with the axis of X, the same fixed amount of deformation would give a point located at a much smaller distance along the curve than on one whose slope makes a large angle with the axis of X, representing a metal with comparatively high modulus of elasticity. In the former case, the point might even be found to lie on the straight part of the line (within the proportional limit), whereas in the latter case it would be more likely to lie beyond the first deflection. That is, a fixed amount of deformation as yield point might fit the stress-strain diagrams representing some metals, but would not then fit those of different characteristics. A yield point to be indicative of the characteristics of the curve resulting from the properties of the metals should not be arbitrarily located in this way, but should be suitably fitted to each individual stress-strain diagram.

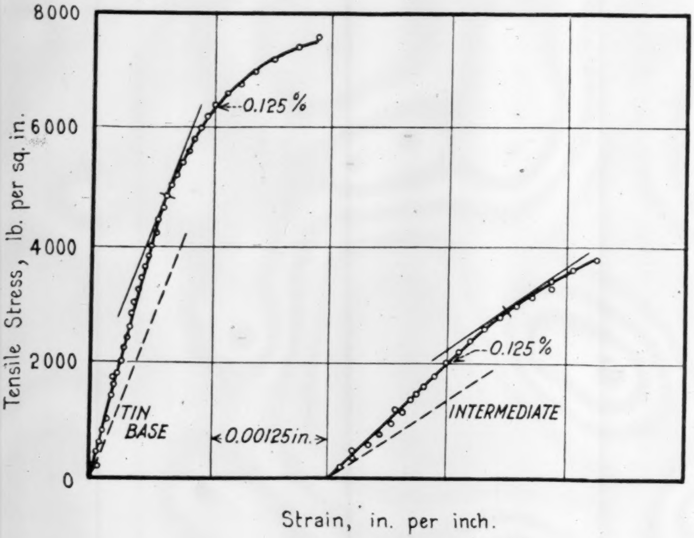

FIG. 1.

It is suggested by George O. Hiers, my asosciate, that instead of a uniform deformatiom being specified as yield point, that the J. B. Johnson method of determining the so-called elastic limit would give figures more clearly defining the comparative characteristics of the metals tested, particularly for those which are more or less plastic in character. This is the method given as Method II for the determination of elastic limit, under Section 17 of the Tentative Methods of Tension Testing of Metallic Materials.[1]

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[1] See p. 1081.—ED.

Mr. Cowan.

An illustration of a comparatively great difference in modulus of elasticity and slope of stress-strain curves is provided by a comparison of the stress-strain diagram of a tin-base Babbitt metal with that of an intermediate alloy (neither tin-base nor lead-base) containing 40 per cent of tin. Curves representing tension tests of alloys of this kind are shown in Fig. 1, with points indicated as found by the J. B. Johnson Method. A comparison of the figures found in this way with figures for yield point of 0.125 per cent deformation, together with compositions of the alloys, are given below:

	Composition, per cent				Yield Point, 0.125-per-cent Deformation, lb. per sq. in	Johnson Apparent Elastic Limit, lb. per sq. in.
	Lead	Tin	Antimony	Copper		
Tin Base	....	88.9	7.4	3.7	6300	4800
Intermediate	48.0	40.0	10.0	2.0	2000	2900

The yield point of 0.125-per-cent deformation appears to fit fairly well the stress-strain curve for alloy No. 1, the point lying a little beyond the bend in the curve. But the point corresponding to the same amount of deformation on the curve for alloy No. 2 is located where the line is practically straight, being well within the part of the curve where there is no marked change of direction, and apparently within what might be taken for this alloy as the proportional limit. It is apparent that any single amount of deformation taken as yield point would not fit both of these curves, and that a report of the amount of tension in pounds, found by the Johnson method, better defines the comparative characteristics of the curves as representing properties of the alloys.

A similar instance is illustrated by the stress-strain diagrams given in U. S. Bureau of Standards *Technologic Paper No. 188*, "Some Properties of White Metal Bearing Alloys at Elevated Temperatures," by John R. Freeman, Jr. Alloy No. 4 of this investigation, containing 61.55 per cent of tin is of intermediate grade, as referred to above. Comparing the yield point, as reported, of 0.125-per-cent deformation, with a point found by the Johnson method for this alloy (which corresponds to A.S.T.M. Alloy No. 6)[1] the following results are shown:

	AT 25° C.	AT 50° C.
Yield point, 0.125-per-cent deformation, lb. per sq. in.	4700	3650
Johnson's apparent elastic limit	5100	4500

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[1] Tentative Specifications for White Metal Bearing Alloys (B 23 - 18 T), *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 538 (1920).

Mr. Cowan. From these figures it is noted that the yield point lies within the point found by the Johnson method. With the other alloys (which are either lead-base or tin-base) reported in the Technologic Paper referred to, the yield point lies beyond the Johnson apparent elastic limit.

In the Appendix under discussion, the alloys on which tests are reported include only lead-base and tin-base alloys, without any intermediate grades. The curves are more nearly similar than would be the case if intermediate grades were included, and the fixed amount of deformation taken as yield point may fit them more uniformly. However, in applying the Johnson method to these curves, it appears that the figures obtained are more indicative of comparative characteristics of the alloys as affected by the addition of impurities than those given in reporting 0.125-per-cent deformation yield point. The tabulation of figures obtained by Mr. Hiers in applying the Johnson method is given in Table I. There is some difficulty in applying this method to the compression curves under discussion, since it is difficult to determine the initial rate of deformation, it being open to question whether there is an absolutely constant rate representing true proportionality.

TABLE I.—COMPARISON OF YIELD POINT (AT 0.125-PER-CENT DEFORMATION) AND J. B. JOHNSON'S APPARENT ELASTIC LIMIT OF TYPICAL ALLOYS WITH ADDED IMPURITIES.

Temperature, 20° C.

Alloy	Impurity, per cent	Yield Point, 0.125-per-cent Deformation, lb. per sq. in.	Johnson Apparent Elastic Limit, lb. per sq. in.
	LEAD BASE		
No. 1	Arsenic, 0.01	3950	2500
No. 2	" 0.14	4100	2800
No. 3	" 0.40	3900	3600
No. 4	" 0.46	4550	3050
No. 13	Zinc, not detected	3850	2100
No. 14	" 0.74	4200	2800
No. 15	" 1.4	4100	3350
No. 5	Copper, trace	4000	3000
No. 6	" 0.55	4100	3000
No. 7	" 1.00	4050	2600
No. 8	" 1.10	4150	3000
	TIN BASE		
No. 9	Arsenic, 0.06	5000	2100
No. 10	" 0.41	6050	2500
No. 11	" 0.51	5600	3900
No. 12	" 3.00	5500	4150
No. 16	Zinc, not detected	5200	3200
No. 17	" 0.42	5300	3800
No. 18	" 0.91	5300	2500
No. 19	" 1.30	5350	2300

TABLE II.—COMPARISON OF YIELD POINT (0.125-PER-CENT DEFORMATION) AND J. B. JOHNSON'S APPARENT ELASTIC LIMIT OF A.S.T.M. TENTATIVE STANDARD ALLOYS.

A.S.T.M. Alloy	20° C.		100° C.	
	Yield Point, 0.125-per-cent Deformation, lb. per sq. in.	Johnson Apparent Elastic Limit, lb. per sq. in.	Yield Point, 0.125-per-cent Deformation, lb. per sq. in.	Johnson Apparent Elastic Limit, lb. per sq. in.
No. 1	4500	2450	2650	1050
No. 2	6100	3350	3000	1100
No. 3	6600	5350	3150	1300
No. 4	5550	3200	2150	1550
No. 5	5050	3750	2150	1500
No. 6	3800	3550	2050	1800
No. 7	3550	2500	1600	1350
No. 8	3400	2650	1750	1200
No. 9	3400	2400	1550	950
No. 10	3350	2250	1850	1200
No. 11	3050	2750	1400	1100
No. 12	2800	2250	1250	950

TABLE III.—COMPARISON OF YIELD POINT (0.125-PER-CENT DEFORMATION) AND J. B. JOHNSON'S APPARENT ELASTIC LIMIT OF TYPICAL ALLOYS WITH ADDED IMPURITIES.

Alloy	Impurity, per cent	20 C.		100 C.	
		Yield Point, 0.125-per-cent Deformation, lb. per sq. in.	Johnson Apparent Elastic Limit, lb. per sq. in.	Yield Point, 0.125-per-cent Deformation, lb. per sq. in.	Johnson Apparent Elastic Limit, lb. per sq. in.
LEAD BASE					
No. 1	Arsenic, 0.01	3950	2600	1800	1300
No. 2	" 0.14	4100	2450	2350	1800
No. 3	" 0.40	3900	3800	2050	1350
No. 4	" 0.46	4550	2400	1800	1650
No. 13	Zinc, not detected	3850	2450	1900	1500
No. 14	" 0.74	4200	3050	2600	1700
No. 15	" 1.4	4100	3900	2300	2000
No. 5	Copper, trace	4000	2850	2250	1300
No. 6	" 0.55	4100	3050	2000	1500
No. 7	" 1.00	4050	3400	2200	1200
No. 8	" 1.10	4150	3300	2250	1000
TIN BASE					
No. 9	Arsenic, 0.06	5000	2750	2950	1850
No. 10	" 0.41	6050	3200	3450	2450
No. 11	" 0.51	5600	3350	3300	1800
No. 12	" 3.00	5500	3900	3150	1600
No. 16	Zinc, not detected	5200	2450	2400	1600
No. 17	" 0.42	5300	3050	3550	1300
No. 18	" 0.91	5300	2250	3100	1200
No. 19	" 1.30	5350	3250	3350	1650

Mr. Freeman.

MR. J. R. FREEMAN, JR.—Mr. Cowan has raised a very interesting point relative to the testing of alloys of the Babbitt metal type.

In the original work[1] on elevated temperature tests of white metal bearing alloys the arbitrary value of 0.125 per cent was adopted as it more generally seemed to best represent the first marked yielding of the test specimen representing the several types of alloys. In the later work this value has been used in order that consistent comparison might be made between the data published in the several reports that have been made. It is admittedly an arbitrary value as is also the value of 0.5 per cent which was proposed by Committee E-1 on Methods of Testing as well as the J. B. Johnson method.

The suggestion to use the J. B. Johnson method is very good. The authors have determined the "elastic limit" by this method of all the alloys discussed in this paper and of the twelve A.S.T.M. tentative standard alloys the properties of which were presented in a previous report.[2]

As of possible interest these values compared to values reported using the 0.125-per-cent deformation method are given in Tables II and III.

With reference to Table III, it is to be noted that the values obtained by the authors using the J. B. Johnson method do not check in many cases the values obtained by Mr. Cowan. The authors found between themselves similar differences due to the personal equation in judging the slope of the tangent at the origin.

The authors agree with Mr. Cowan that the value obtained using the J. B. Johnson method is not in fact an elastic limit and would point out further that metals of this type have no appreciable elastic properties. It is, therefore, incorrect to speak of the limit of proportionality, inasmuch as over no portion of the stress-strain curve is the ratio of stress to strain a constant. In stating values for modulus of elasticity the method of obtaining the modulus should be stated, whether it is based on the initial slope of the curve, a tangent to the curve or the secant modulus at some stress value.

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[1] John R. Freeman, Jr., and R. W. Woodward, "Some Properties of White Metal Bearing Alloys at Elevated Temperatures," U. S. Bureau of Standards *Technologic Paper No. 188*.

[2] John R. Freeman, Jr., "The Physical Properties of the A.S.T.M. Tentative Standard White Metal Bearing Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 207 (1922).

REPORT OF COMMITTEE B-3
ON
CORROSION OF NON-FERROUS METALS AND ALLOYS

During 1922, Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys decided that its main endeavor should be the work of developing standard corrosion tests and determining their necessary conditions and their accuracy. It was recognized by the committee that the types and conditions of corrosion of commercial interest are varied and numerous and that in consequence, the technique of the determination of corrosion resistance of metals and alloys varied over a rather broad field. As a first step in its work, the committee isssed a questionnaire as shown below:

GENERAL QUESTIONNAIRE

1. With which types of corrosion and of corrosion tests have you or has your laboratory been most concerned and what data have you secured?

(*A*) Suggested types of corrosion:
- (*a*) Total immersion, liquid at rest or in motion;
- (*b*) Alternate immersion;
- (*c*) Spray or mist;
- (*d*) Gaseous or atmospheric;
- (*e*) With galvanic or concentration acceleration.

(*B*) Suggested types of corrosion-resistance tests:
- (*a*) Service—actual results from service;
- (*b*) Service duplication—laboratory controlled, duplication of service conditions;
- (*c*) Accelerated tests.

Do you recognize other classifications more useful than the above?

Do you consider types of test (*b*) and (*c*) above to give useful and practical results? In particular what accelerated tests have you developed (or have knowledge of) which do appear to give results of practical value?

2. Which type of corrosion do you consider most important commercially?

3. What bibliography of the subject have you available? Will you enclose copy with your reply?

4. Corrosion tests are of necessity of widely different character in all respects, rendering the task of their standardization a very difficult one. What in your opinion should be the direction of the first effort of the committee in attacking the problem? Should it be along one of the lines suggested below, or can you suggest a more useful line of attack?

(*a*) Discussion of present best practice in corrosion testing, bringing out controlling conditions and leading to a monograph by the committee on corrosion testing;

- (*b*) Standardization of method of describing tests, of expressing results and the accuracy of their duplication;
- (*c*) Actual development of standard methods of tests for different types of corrosion service or of accelerated tests;
- (*d*) Actual progress of cooperative corrosion tests of different materials.

5. Give your definition of corrosion. Distinguish between it and erosion and similar phenomena.

- (*a*) What do you consider to be the most useful criteria of corrosion resistances? Suggestions: loss in weight, penetration of corrosion, contamination of corroding agent, catalytic effect on reaction, general deterioration throughout.
- (*b*) Can you suggest better terms than corrosion resistance and corrosion resistant? Do you approve of non-corrosive, incorrodible, etc.?

DETAIL OF TECHNIQUE OF CORROSION TESTING OF TYPES SUGGESTED ABOVE

Please discuss under the heads listed below, or under any other if you cannot agree with the classification, the details of what you consider the best practice in corrosion testing.

6. *Corrosion by Total Immersion:*

- (*a*) Description of metal or alloy:
  - (1) Chemical analysis;
  - (2) Physical conditions; that is, rolled, forged, etc.;
  - (3) Conditions of surface; that is, polished, scale, ground, etc.;
  - (4) Grain size.
- (*b*) Preparation and form of test piece:
  - (1) Edges, corners, surface;
  - (2) Preparation of surface; cleaning before and after test;
  - (3) Use of same test piece for more than one test; re-preparation of sample.
- (*c*) Preparation and maintenance of corroding agent—(solution):
  - (1) Concentration and changes in;
  - (2) Volume and relation of volume to surface of specimen;
  - (3) Renewal and contamination during test (concentration cell action);
  - (4) Presence and concentration of dissolved gases—oxygen and carbon dioxide;
  - (5) Presence of solid particles and control.
- (*d*) Immersion of specimen:
  - (1) Depth;
  - (2) Support of supporting material;
  - (3) Other samples in same solution.
- (*e*) Temperatures of system—regulation.
- (*f*) Time exposure. Is determination of time (corrosion rate) advisable? Rejection of results of first few hours test.
- (*g*) Velocity and agitation control.
- (*h*) Effect of light.
- (*i*) Weighing and cleaning for weighing (fingers, brush, file); handling of pitted samples (grinding down to base of pits).

(*j*) Expression of results:
  (1) Quantitative, proper unit or units; loss of weight, penetration, loss of strength;
  (2) Qualitative; description of appearance, coating and surface deposits (microscopic examination);
  (3) Photographs.

(*k*) Probable error and accuracy of duplication. Should not results include statement of order of precision?

(*l*) Other factors.

7. *Corrosion by Alternate Immersion:*

In addition to items of No. 6:

(*m*) Period of alteration; intermittent drying or not.

(*n*) Description of atmosphere.

8. *Corrosion by Spray or Mist:*

In addition to items of No. 6:

(*o*) Velocity of spray.

(*p*) Particle size and concentration.

(*q*) Description of phases; liquid, solid and gaseous.

9. *Gaseous or Atmospheric Corrosion:*

In addition to items of No. 6:

(*r*) Moisture control.

(*s*) Light control.

(*t*) Velocity control.

(*u*) Dust control.

10. *Corrosion with Galvanic or Concentration Cell Acceleration.*

These will probably be special cases.

11. Which of the above factors do you consider to be the most important conditions governing rate of corrosion? Have you discovered any fundamental laws or relations obtaining in corrosion phenomena.

CONDENSED SUMMARY OF REPLIES TO QUESTIONNAIRE

All replies to the questionnaire were referred to a sub-committee for consideration. In general, the opinions of those who answered the different questions were in substantial agreement and in sympathy with the suggestions of the questionnaire itself. In some cases, however, a variety of opinions was expressed. Therefore, although it is difficult to state in a few words the condensed opinion of all of these answers, this has been attempted below.

In this condensed summary, an attempt is made to express briefly the combined opinions of those furnishing answers to the questionnaire in so far as a definite direction or sense of these opinions can be discerned. The replies will be summarized under the numbers of the original questionnaire.

1. There was a general agreement that the questionnaire classification of types of corrosion and of tests was substantially correct and useful. In considering the different types of tests, there was divergence of opinion as to the usefulness of accelerated tests but all agreed that the results of such tests should be applied to the prediction of service behavior only with great caution.

There were some general data of corrosion resistance available but most of the replies held that their own data were rather too special to be of general application.

Two particular accelerated tests of interest were mentioned: namely, an electrolytic one developed by the U. S Bureau of Mines and one recommended by F. L. Antisell, which he calls the "Method of Galvanic Couples."

The interest of those answering the questionnaire seemed to be pretty generally distributed between the other types of corrosion and corrosion-resistance tests and no one of these could therefore be singled out as being especially favored.

2. Here again it seems impossible to single out from the replies any particular corrosion problem or type of corrosion which was agreed to be the most important commercially, although the condenser tube problem, the problem of trolley wire, the corrosion of metals in mine waters and that of pipes and fittings were prominently mentioned.

3. Several bibliographies on the subject were available although some of these were admitted to be incomplete.

4. There is rather emphatic agreement in sympathy with the questionnaire as to the best procedure for the committee to follow. This is the basis of the sub-committee's recommendation below.

5. Naturally, a variety of definitions were given in the replies but in substance all agreed that corrosion is a chemical attack and erosion a mechanical attack; all of the definitions would therefore include, as corrosion, the attack of metals by gases at high temperatures.

A suggested definition of corrosion is the act of chemical alteration of metals or alloys by contiguous media and having its origin at the surface of contact.

All correspondents agreed that under (*a*), all of the criteria mentioned were useful but that the extent of penetration was the most generally useful. Under (*b*), the terms "non-corrosive" and "incorrodible" were emphatically rejected and in the absence of better ones there was agreement that "corrosion resistance" and "corrosion resistant" should be used.

6. (*a*) All agreed that the metal should be defined chemically, physically, and structurally in an unambiguous manner.

(*b*) There was general agreement on the method of preparation of the test piece but naturally not on its form; the specimen should be cleaned with some abrasive and all grease removed; in addition, some recommended pickling the specimen before test. In general, it was not recommended that the specimen be used for more than one test, at least in different media.

(*c*) The point was made that concentration should be expressed in terms of units of mass per unit of volume and not as a percentage. There was divergence of opinion on the question of volume of solution and the question of renewing it. Some recommended that the volume of solution be sufficiently large that there be no necessity for its renewal during the period of test.

All agreed that the presence of dissolved gases, particularly of oxygen, was of primary importance but many had not undertaken to control it in their test work. The consensus of opinion seemed to be that these gases can best be controlled by eliminating them entirely or by saturating the solution with them.

(*d*) There was divergence of opinion on the depth of immersion but all recognized that it should be noted. It is pointed out, however, that provided the concentration of dissolved gases is otherwise controlled, the depth of immersion should have no significance. Most of the correspondents agreed that samples of different materials should not be placed in the same solution.

(*f*) There was disagreement on the matter of rejecting results of the first few hours test, some expressing the opinion that these results should also be observed and utilized.

(*g*) All agreed that velocity and agitation should be controlled and specified.

(*h*) The consensus of opinions was that light exercises no effect on the results of corrosion tests.

(*i*) The detail of procedure described was not sufficient to enable a conclusion to be drawn.

(*j*) The consensus of opinion was that the most general expression of results should be the loss in weight per unit of area, although the appearance should also be described.

(*k*) There was agreement that the probable error should be given in such measurements.

7. Not many of the correspondents had had experience with this type of corrosion, but by some it was considered to be an admirable test. There was a divergence of opinion as to the intervals of dry and wet exposure, some holding that the intervals should be equal, one claiming that the sample should actually become dry in the dry interval and another claiming equally emphatically that the intervals should not be long enough for the sample to dry.

8. For corrosion by spray or mist, the apparatus described by Finn[1] was recommended by several. It was pointed out with regard to particle size that perhaps sufficient provisions were made to standardize this by placing the sample out of the direct stream of the spray by the use of baffles.

9. Little information was given on gaseous or atmospheric corrosion beyond the agreement that the conditions of exposure such as temperature, presence of gases, etc., should be noted.

10. Here again, with respect to galvanic acceleration, little information was given, although it was pointed out that the A.S.T.M. should follow the established practice of referring to noble metals as electro-positive. One or two correspondents were very much impressed with the value of tests involving the feature of galvanic action or concentration cell action.

11. As was to be expected, a somewhat varied reaction to this question was evident in the replies, there being rather general agreement, however, that the presence and concentration of oxygen, the temperature and the degree of agitation of the corroding medium were the principal factors influencing the corrosion rate.

CONCLUSIONS FROM REPLIES TO QUESTIONNAIRE

Certain conclusions seemed to be evident from a consideration of the replies received, the most important being the unanimity of opinion that it should be the function of Committee B-3 to attempt to standardize the practice of corrosion-resistance testing. There seemed to be agreement that the above could best be done by the preparation of a description in detail of the procedure in the carrying out of various corrosion tests. Following this and really a part of the task of preparing requirements for corrosion-resistance testing, a program of cooperative tests should be laid out with the idea not so much of determining the properties of any particular metal as of demonstrating the usefulness and precision of the proposed specified practice.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XVIII, Part I, p. 237 (1918).

The interest of those answering the questionnaire seemed to be distributed pretty generally over all of the types of corrosion suggested in question No. 1. The sub-committee therefore recommended that a number of sub-committees be appointed to undertake the preparation of what might be a "specification description" of standard practices for conducting corrosion-resistance tests, to prepare definitions of various terms used in connection with the work on corrosion and to initiate a program of cooperative tests to test these standard practices.

Sub-committees were therefore appointed as follows and were instructed to begin active work at once with a view toward having actual testing started within a year:

Sub-Committee I on Total Immersion Test;
Sub-Committee II on Alternate Immersion Test;
Sub-Committee III on Spray Test;
Sub-Committee IV on Definitions; and
Sub-Committee V on Accelerated Electrolytic Test.

These sub-committees have been actively at work upon the subjects assigned to them. At a meeting of Committee B-3 held at the Society's headquarters on October 25, 1923, a program of cooperative tests was formulated on the recommendations of the sub-committee, and at another meeting of the committee held at Pittsburgh, March 12, 1924, the details of the tests were agreed upon.

Briefly, the program calls for the making of four tests—total immersion, alternate immersion, spray, and accelerated electrolytic tests—using in each the following six solutions: (1) Sodium chloride, (2) hydrochloric acid, (3) acetic acid, (4) sodium hydroxide, (5) ammonium hydroxide and (6) potassium bichromate. The following six metals, which are referred to in detail below, will be tested by each method and in each solution: (1) Admiralty metal, (2) aluminum, (3) copper, (4) lead, (5) nickel and (6) zinc.

Following are the directions for the preparation of solutions and specimens and the detailed procedures to be followed in each test.

SOLUTIONS TO BE USED IN TESTS

The following directions shall be observed in the preparation of the six solutions to be used in these tests:

All solutions shall be made up in Pyrex glass with freshly boiled distilled water and stored in Pyrex glass flasks, stoppered with rubber stoppers. All solutions shall be exactly normal within limits of experimental error. All tests shall be run at 30° C. ± 1° C.

1. *Sodium Chloride Solution.*—Baker & Adamson's c.p. sodium chloride, without further purification, shall be used for this solution.

2. *Hydrochloric Acid.*—Chemically pure hydrochloric acid shall be used. This shall be diluted to approximately 20 per cent, and distilled through a 12-in. Hempel column, filled with large glass beads, at the rate of 45 to 60 drops per minute. The middle third of the distillate only shall be used for the preparation of the normal HCl solution.

3. *Acetic Acid.*—Chemically pure glacial acetic acid shall be used. The fraction to be employed shall be distilled from a side-necked distilling flask at the rate of 45 to 60 drops per minute. The middle third only shall be used for the preparation of the normal acetic acid.

4. *Sodium Hydroxide Solution.*—As it is practically impossible to prepare pure sodium hydroxide, a material of constant percentage of impurities will be used instead. This shall be prepared by making up a saturated solution of c.p. sodium hydroxide in distilled water at a temperature somewhat above room temperature. This solution shall then be allowed to stand (in Pyrex glass) for not less than two weeks. On account of the low solubility of other sodium salts in strong NaOH solution, the resulting (approximately 40 per cent) solution will be very low in carbonates, sulfates, and chlorides, and of definite composition, being saturated with each of these compounds. From this solution the normal sodium hydroxide solution shall be prepared and stored in Pyrex glass, tightly stoppered.

5. *Ammonium Hydroxide Solution.*—The stock solution shall be prepared by distilling off the ammonia from c.p. ammonia solution into distilled water through a 12-in. Hempel column filled with large glass beads. The gas coming off before the temperature reaches 50° C. shall be discarded, and only that coming over between 50 and 75° C. used for making the normal NH_4OH solution.

6. *Potassium Bichromate Solution.*—The c.p. reagent shall be recystallized twice from distilled water and dried at 150° C.

MATERIALS TO BE USED IN TESTS

The six metals to be used in the tests have been supplied free of charge by the following companies:

1. Admiralty Metal	Scovill Manufacturing Co.
2. Aluminum	Aluminum Corporation of America.
3. Copper	American Brass Co.
4. Lead	National Lead Co.
5. Nickel	International Nickel Co.
6. Zinc	New Jersey Zinc Co.

The composition in each case is that of a regular commercial product. Fifty sheets 6½ by 36 in. and 0.25 cm. in thickness have been obtained of each material. Wherever possible, all sheets have been rolled from the same ingot or at least consecutive ingots and the manufacturers have submitted reports giving the chemical analysis, the physical properties and a record of the metallurgical treatment (annealing, reduction, etc.) of the materials. Each sheet has been stamped by a special identification stamp of the committee and all of the sheets have been shipped to the U. S. Bureau of Standards, Washington, D. C.

The Bureau of Standards has agreed to act as custodian of this material and to cut it up into pieces of the requisite size for the tests and to send out the test pieces to the various persons who will cooperate in the tests. Specimens will be rectangular, 5 by 2.5 by 0.25 cm., and will be drilled with a $\frac{1}{8}$-in. hole $\frac{1}{4}$ in. from the short edge of the piece, ready for suspension. In the case of the alternate immersion test, this hole will be drilled in the center of the long edge. The Bureau of Standards has also agreed to make chemical, physical, and metallographic studies of each of the six materials. This work is already under way and will probably be completed by the time the cooperative tests in other laboratories are completed.

PREPARATION OF SPECIMENS FOR TESTS

Since the committee is primarily interested in testing the different tests rather than the metals, the method adopted for the preparation of the specimens must necessarily be such as to eliminate variables in the specimens as introduced in the tests by the various cooperators. The methods adopted for preparation of specimens are given below:

Specimens of Admiralty metal, aluminum, copper, nickel and zinc shall be prepared as follows: Rubbing with No. 0 Hubert (French) emery paper followed by No. 00 Hubert (French) emery paper. Rub with the No. 0 emery paper so that the scratches will be vertical when the specimen is hung in the solution and with the No. 00 paper at 90 deg. to this. The emery paper shall be held on a wooden block covered with felt, the polishing block to be 1 in. wide, $2\frac{1}{2}$ in. long and the paper cut in $2\frac{1}{2}$-in. squares. Use a fresh piece of No. 00 paper for each specimen. Pressure during rubbing shall be light so as to cause no surface flow, and the resultant finish shall show no evidence of a glossy polish. Follow the rubbing by a bath in alcohol, rubbing the surface lightly with a cotton swab, and rinse in ether in order to remove all grease, finger prints, etc. Specimens shall be prepared immediately before testing is started.

Specimens of lead should not be prepared by rubbing with emery, as it is practically impossible to perform this operation without causing surface deformation or flow of the lead. Specimens shall be prepared by a removal of grease and a removal of oxide film as follows: Rub the surface of the lead lightly with cotton soaked in ether. Immerse pieces in 40-per-cent acetic acid at ordinary temperature, allow to remain until surface is bright, remove and rinse in slightly warm water and dry by rinsing first in alcohol and then in ether. (If the pieces of metal are dried with alcohol and ether at ordinary room temperature, the evaporation of the ether will cool them below room temperature and moisture will tend to condense on them resulting in a tarnished surface. The purpose of the warm water is to keep the metal sufficiently above room temperature so that this will not occur.) Specimens shall be prepared immediately before testing is started.

TOTAL IMMERSION TEST

The total immersion test adopted by Committee B-3 is essentially that developed at the Jackson Laboratory of the E. I. du Pont de Nemours and Co. and described by them as their "Standard Static Corrosion Test." Studies have been made in the above laboratory of the effects on the results of this test of variations in size and form of test piece, volume of corroding solution, temperature of corroding solution, time of exposure, and cleaning of test pieces. It appears best to eliminate these variables as much as possible by the adoption of a standard method of testing as described below. All tests for Committee B-3 shall be in accordance with these instructions:

Corroding Solution.—Use 250 cc. of each corroding solution per test. Use solutions as described under "Solutions to be Used in Tests."

Test Piece.—Use piece 5 by 2.5 by 0.25 cm. (area 29.69 sq. cm.). Dimensions shall be accurate to 0.25 mm. in order to save time of measurement and area calculation. Eight test pieces of each material will be required for each solution.

Preparation of Piece.—Prepare the surface of the test piece in accordance with instructions given under "Preparation of Specimens for Test."

Temperature.—Run tests at a temperature of 30° C. ± 1° C., preferably by immersing the solution containers in a thermostatically controlled water bath or by operation in a constant temperature room.

Checks.—Run tests in quadruplicate for checking purposes. Never place test pieces of different metals in the same container. It is permissible to place two pieces of the same metal in the same container but they should not be in contact.

Apparatus.—The apparatus shall comprise the following: A flask or wide-mouth bottle of about 500-cc. capacity, equipped with loosely fitting stopper, made of a material which will not be affected by the corroding solution; a glass hook of such length as to allow of suspending the test piece in 250 cc. of solution placed in the container; a 5-mm. glass tube inserted through the stopper to the bottom of the container so as to allow of bubbling a stream of CO_2-free air through the solution, and so placed that the ascending bubbles do not strike the test piece; and a purification train for air, to consist of a soda-lime tower followed by two wash bottles containing CO_2-free distilled water.

Procedure.—Immerse four test pieces in the solution in flasks or bottles not equipped with tubes for aëration. Immerse four other pieces in the solution in flasks or bottles equipped with tubes for aëration and with air bubbling at the rate of 15 to 20 bubbles per minute. Expose test pieces for 48 hours to corroding solution. Remove from solution, wash thoroughly in a stream of water and remove any coating. This cleaning may be done by dissolving off the coating (lead sulfate in ammonium acetate solution, lead chloride in hot water, etc.) or by rubbing and scouring with or without a soft powder as a mild abrasive. Wash in alcohol and ether and dry thoroughly; then weigh. Immerse in the corroding solution for a second 48-hour period. After the second 48-hour immersion, clean and weigh again as described above. From the loss during the last 48 hours, calculate the average rate of corrosion as indicated below.

Pitting.—In case the metal develops pitting, this factor shall be included in the results. Determine the magnitude of this effect by measuring with depth micrometer or by grinding down on a metallographic grinding set until all the pits have just disappeared and solid metal is reached. Determine loss of weight during this grinding and calculate pitting as indicated below.

Calculations:

W = loss in weight in grams of test piece during second 48-hour immersion;
A = area of test piece in square centimeters;
S = density of metal in grams per cubic centimeter;
T = time of exposure in hours;
C_p = rate of corrosion in centimeters penetration per month.

$$C_p = \frac{24 \times 30 \times W}{A\ S\ T} = \frac{720W}{A\ S\ T}$$

C_w = rate of corrosion in mg. per sq. cm. per day.

$$C_w = \frac{24W}{A\ T}$$

P = loss in weight in grams due to grinding out pits;
p = depth of deepest pit as measured by micrometer;
D = rate of penetration of metal by both normal corrosion over the entire surface and local action due to pitting.

$$D = 720\ \frac{W + P}{A\ S\ T} \quad \text{or} = C_p + 720\ \frac{p}{T}$$

Records.—Keep accurate record of all tests and data on a form as described under "Form for Test Data." Fill in all blanks of form possible, making descriptions as concise and explicit as possible. Use back of form for additional remarks, data and calculations.

ALTERNATE IMMERSION TEST

The alternate immersion test adopted by Committee B-3 is based on the one developed at the Bureau of Standards, Washington, D. C. The work done to date, however, indicated the need of an interrupted alternate immersion test in which the test piece is held in the air for a considerable period of time between immersions so as to allow equilibrium to be established between the piece and the atmosphere. The methods of suspension, time per cycle, atmospheric control, etc., have all been considered and standards adopted in order to eliminate variables and to make results of independent investigators directly comparable. All tests for Committee B-3 shall be in accordance with the following instructions:

Corroding Solution.—Same as in Total Immersion Test.

Test Piece.—Same as in Total Immersion Test, except that suspension hole shall be drilled in center of long edge rather than short edge of piece. Eight test pieces of each material will be required for each solution.

Preparation of Piece.—Same as in Total Immersion Test.

Temperature.—Same as in Total Immersion Test.

Checks.—Same as in Total Immersion Test.

Apparatus.—The apparatus shall consist of any convenient arrangement which will allow of suspending test pieces by a cord in such a manner as to produce an up-and-down motion at predetermined intervals. For alternate immersion and exposure to atmosphere of equal time periods, a crank operated by a motor through a reducing gear will suffice. The samples shall be suspended on a cord extending from the crank over a pulley in such a manner that as the crank revolves, the sample is raised and lowered, producing alternate immersion. The test piece shall be attached to the cord by means of a glass hook, passing through a hole in the longer edge of the piece. The diameter of the crank stroke shall be 4 in. and the crank shall make one revolution in 3 minutes.

In the Interrupted Alternate Immersion Test, the apparatus shall be so designed as to interrupt the 3-minute cycle for 12 minutes when the test piece is at the top of its path. The result is a 15-minute cycle and the test piece shall be in the solution only $1\frac{1}{2}$ minutes of this time. The air over the apparatus in the Interrupted Alternate Immersion Test shall be circulated by an electric fan placed at some distance in order to make the effect uniform for all pieces under test. A suitable apparatus for this test can be made by using a clock with mercury contacts so spaced as periodically to operate relay switches which in turn will operate the starting switch on the small motor in the regular Alternate Immersion Test apparatus so as to stop the motor for 12 minutes when the crank is at the top of its regular 3-minute cycle. Another method is by building the apparatus so as to obtain the up-and-down motion by means of cams and to get the proper time period by worm-and-gear reduction from a constant speed motor—a simple shifting of cams and gears will allow the change over. One motor can be made to operate one-half the apparatus on the 3-minute cycle and the other half on the 15-minute cycle at the same time, if it is so desired.

In both the Alternate and the Interrupted Alternate Immersion Tests, the solution container shall be of glass and shall have a capacity of 500 cc. or more sufficiently large to keep the test piece free from contact with the sides. One piece shall be tested in one container at a time.

Procedure.—Place solutions in the proper number of containers and bring them to the desired temperature. Run four test pieces of each material in the Alternate Immersion Test and four more in the Interrupted Alternate Immersion Test. After preparing the surfaces of test pieces as described above, weigh the pieces carefully and attach them to the glass hooks so that as the apparatus operates, the level of solution in the containers is at a point representing the center of motion of the pieces. The duration of the test is 24 hours. At the end of this time remove the pieces, note their appearance and remove the products of corrosion by washing thoroughly in a stream of water and rubbing and scouring with or without a soft powder as a mild abrasive, or by dissolving off the coating (lead sulfate in ammonium acetate solution, lead chloride in hot water, etc.). Wash in alcohol and ether, dry thoroughly and weigh. From the loss in weight, calculate the rate of corrosion as in the Total Immersion Test.

Pitting.—Same as in Total Immersion Test.

Calculations.—Same as in Total Immersion Test.

Records.—Same as in Total Immersion Test.

SPRAY TEST

The spray test adopted by Committee B-3 makes use of the apparatus developed at the Bureau of Standards some years ago for testing the resistance of metallic coatings to salt water. This apparatus is described in Bureau of Standards *Circular No. 80* on "Protective Metallic Coatings for the Rust Proofing of Iron and Steel." Committee B-3 has decided to investigate the adaptability of this apparatus for use with other than salt solutions and also for use in testing homogeneous materials and not metallic coatings. All tests shall be in accordance with the following instructions:

Corroding Solution.—Use solutions as described under "Solutions to be Used in Tests." Use sufficient solution to fill the lower end of the spray box to a depth of approximately 4 in. Maintain this level as nearly as possible by frequent additions.

Test Piece.—Same as in Total Immersion Test. Eight test pieces of each material will be required for each solution.

Preparation of Piece.—Same as in Total Immersion Test.

Temperature.—Run tests at a temperature of 30° C. ± 1° C., if possible. If this is not possible, take temperature readings at frequent intervals, for example two times per day, and record the readings as part of the test.

Checks.—Run each series of tests in quadruplicate for checking purposes. No test piece shall be in contact either with another or with the wall of the container, but any number of pieces of the same or different materials may be run at the same time in the same spray box.

Apparatus.—The apparatus shall consist of a spray box of stone ware as described in *Circular No. 80* of the Bureau of Standards and equipped with a glass atomizer. The parts of the atomizer shall be rigidly fastened together so that the distance between the two orifices (for liquid and air) will not undergo any change during use. A baffle plate shall be inserted in the direct path of the "spray" of the atomizer so that only the finest mist will be in contact with the test pieces. Compressed air for the atomizer of 8 to 10-lb.-per-sq.-in. pressure shall be passed through a purification train consisting of a closely packed filter of cotton wool to absorb oil, a soda-lime tower to remove CO_2, followed by two wash bottles containing CO_2-free distilled water.

Procedure.—Weigh the test pieces, the surfaces of which have been prepared as prescribed above, and string on the glass rods of the spray box or hang by means of glass hooks. Two series of each metal shall be run. For series I, run the test for 2 weeks and without removing any of the adhering corrosion product, wash the test piece carefully, dry for one hour at 50° C. and weigh. Return the test piece to the spray box for another period of test as before. Repeat this procedure for a total of four 2-week periods, or 8 weeks actual exposure; then after noting change in weight, clean the test piece carefully and determine the total loss for the entire 8-week period.

For series II, run the test for four 2-week periods as in series I, but at the end of each 2-week period, wash and clean the test piece with a bristle brush, so as to remove as much as possible of the corrosion product, dry for one hour at 50° C. and weigh.

Pitting.—Same as in Total Immersion Test.

Calculations.—Same as in Total Immersion Test.

Records.—Same as in Total Immersion Test; also, add such data as daily temperatures, weights after each 2-week period, general condition of surface of test pieces, number and date of renewals of solutions, air pressure, purification train used, etc.

ACCELERATED ELECTROLYTIC TEST

The accelerated electrolytic test adopted by Committee B-3 is that developed at the U. S. Bureau of Mines in Pittsburgh, by R. J. Anderson and G. M. Enos. The test is described in some detail in *Bulletin No. 6*, Coal Mining Investigations, Carnegie Institute of Technology, Pittsburgh, 1923. In order to eliminate variables as much as possible in the work of various testers for Committee B-3, it has been deemed best to adopt certain standards such as temperature, size of test specimen, current imposed, revolutions per minute, etc., as described below. All tests for Committee B-3 shall be in accordance with these instructions:

Corroding Solution.—Same as in Total Immersion Test.

Test Piece.—Same as in Total Immersion Test. Four test pieces of each material will be required for each solution.

Preparation of Piece.—Prepare the surface of each test piece in accordance with instructions given under "Preparation of Specimens for Test," but before washing in alcohol and ether, solder a piece of copper wire (No. 20 standard wire gage or other suitable size, if preferred) to one end in the middle of the width. The wire shall be of proper length to suspend the sample suitably from the anode chucks. The soldered contact shall cover an area at the top of the test piece of less than $\frac{1}{4}$ in. on a side, that is, $\frac{1}{16}$ sq. in. Wash with alcohol and ether as described in "Preparation of Specimens for Test" and then, being careful not to touch the specimen with the hands and using a small brush, coat the soldered contact and part of the copper wire immediately above with a coating of beeswax and paraffin, Montan wax and paraffin, or other suitable coating so as to prevent corrosion of the solder and the wire.

Temperature.—Same as in Total Immersion Test.

Checks.—Run tests in quadruplicate for checking purposes. Never place test pieces of different metals in the same container.

Apparatus.—Any suitable type of electrolytic-analysis apparatus with rotating anode connections may be used. A 12-spindle apparatus designed and built in the U. S. Bureau of Mines especially for this work is shown in *Bulletin No. 6*, Coal Mining Investigations, Carnegie Institute of Technology, referred to above. As many cells as desired may be arranged in series. The speed of rotation of the anode spindle shall be 100 r.p.m. and shall be kept as constant as possible. Direct current shall be used and regulation shall be made by lamp-bank or other suitable resistor. The imposed current shall be 0.18 ampere per sq. dcm. of surface area exposed and should be maintained as constant as possible. A sensitive milliameter, reading to 0.001 ampere, shall be in series with the resistor and cells. The cells shall be heavy-walled glass beakers, flasks or wide-mouth bottles of about 500-cc. capacity. The cathodes shall be platinum wires, No. 20 standard wire gage (B. & S. gage), that is, 0.032 in. in diameter.

Procedure.—Place 250 cc. of corroding solution in each cell. Bring the installation to proper temperature. Weigh the test piece and wire very carefully. Suspend the test piece from the anode chuck so that the piece is totally immersed. Set anode to rotating at 100 r.p.m. Apply a current of 0.18 ampere per sq. dcm. (0.053 ampere). After 8 hours, remove specimens and wash in running water to remove any loose corrosion products. Dry in a desiccator. (Use no alcohol and ether as this will dissolve paraffin and change the weight readings.) Weigh carefully.

Pitting.—Same as in Total Immersion Test.

Calculations.—Same as in Total Immersion Test.

Records.—Same as in Total Immersion Test; also, add such items as voltage drop per cell, chemical analysis of the electrolyte after corrosion, and observations on the nature of the coatings and precipitates formed.

DATA FORM FOR RECORDING TESTS

In order to standardize the method of keeping records and reporting the tests conducted for the committee, a form has been prepared as shown below. Each laboratory cooperating with the committee in its work will be given an adequate supply of these forms, so that all reports can be assembled and classified and studied by the committee at some later date.

RECORD OF CORROSION TEST

Date..............................

AT..............................

Material, ... Type of Test, ... Solution, ... Concentration, ... Temperature..............

	Symbol								
Test									
Test Piece No									
Length, cm									
Width, cm									
Thickness, cm									
Area, sq. cm	*A*								
Weight before test, g									
Weight after test, g									
Change in weight, g	*W*								
Time of Start									
Time of Finish									
Hours Run	*T*								
Density, g. per cm	*S*								
Temperature Record									
First Appearance of Corrosion									
Appearance of Surface									
Nature of Pitting									
Depth of Pitting, cm	*p*								
Weight after Grinding, g									
Loss in Grinding, g	*P*								
Corrosion Rate, cm. per month	*Cp*								
Corrosion Rate, mg. per sq. cm. per day	*Cw*								
Corrosion Penetrating, cm. per month	*D*								

LABORATORIES CONDUCTING TESTS

The committee has been endeavoring to arrange for tests in as many different places and by as many different people as possible. Sufficient material for tests is available for fully twice the number that have so far volunteered. In some cases, all four tests are to be run at the same time, whereas others are planning on only one or two types of test. The list of cooperators in the testing work at present follows:

	TYPE OF TEST			
	TOTAL IMMERSION	ALTERNATE IMMERSION	SPRAY	ACCELERATED ELECTROLYTIC
Aluminum Corporation	..	..	√	..
F. L. Antisell, Raritan Copper Works	..	..	..	√
W. H. Bassett, American Brass Co.	√	√	√	..
D. Basch, General Electric Co. M. F. Sayre, Union College T. S. Fuller, General Electric Co.	..	..	√	√
W. D. Bigelow, National Canners' Association	√	..	..	..
A. G. Blakeley, Philadelphia and Reading Coal Co.	√	..	..	..
F. G. Breyer, New Jersey Zinc Co.	√	√	√	..
Bureau of Engineering	√	√	√	..
W. S. Calcott, Jackson Laboratory	√	..	..	..
G. H. Clamer, Ajax Metal Co.	√	..	..	..
W. A. Cowan, National Lead Co.	..	√	..	..
D. K. Crampton, Chase Metal Works	..	√	..	..
G. K. Elliott, Lunkenheimer Co.	..	√	..	..
F. F. Farnsworth, Western Electric Co.	..	√	..	..
A. C. Fieldner Bureau of Mines	√	√	√	√
A. E. Flowers, De Laval Separator Co.	√	√	√	..
Max Hecht, Duquesne Light Co.	..	..	..	√
Zay Jeffries, Aluminum Manufacturers	..	..	√	..
E. L. Lasier, Emergency Fleet Corporation	√	..	..	..
R. J. McKay P. D. Merica — International Nickel Co.	√	√	..	..
W. B. Price, Scovill Manufacturing Co.	..	..	..	√
H. S. Rawdon, Bureau of Standards	√	√	√	√
W. D. Richardson, Swift and Co.	√	√	√	√
J. W. Stillman, E. I. du Pont de Nemours and Co.	√	..	..	..
J. Strauss, Naval Ordnance Bureau	..	..	√	..
W. R. Webster, Bridgeport Brass Co.	..	..	..	√
J. K. Wood, Westinghouse Electric Co.	..	..	..	√
Totals	14	12	11	9

This report has been submitted to letter ballot of the committee, which consists of 38 members, of whom 36 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

SAM TOUR,
Secretary.

E. C. LATHROP,
Chairman.

[For a discussion on corrosion tests, see the discussion of the paper by H. S. Rawdon, A. I. Krynitsky and W. H. Finkeldey, "Types of Apparatus Used in Testing the Corrodibility of Metals," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).—ED.]

REPORT OF COMMITTEE C-1
ON
CEMENT

During the past year, sub-committees of Committee C-1 on Cement have had under consideration several phases of the specifications either as proposals for modifications of the requirements or for the improvement of the methods of tests. To aid in this work, copies of British, Canadian and French specifications for portland cement have been distributed to the members of the committee. Points of difference have been examined and compared with the American standard. Adding incentive to these studies, data and suggestions have been received from various sources throughout the country. These have been given due and careful consideration by the members of the several sub-committees. The net results of these activities are that Committee C-1 has considered both major and minor phases of the requirements and methods of tests with the objective of possible betterments.

Among the major questions carefully considered by the committee are:

1. A recommendation by the Sub-Committee on Specific Gravity was made that the requirement for specific gravity be dropped from the specifications. Committee C-1 believes that ultimately this requirement should be withdrawn but since it is now optional, the committee believes formal action can be left until there arise other questions of more import requiring changes in the standard specifications.

2. It has been urged upon the committee that there should be some shorter time strength test than the 7-day mortar test. This has led to a suggestion that the specification for the 24-hour neat test be reincorporated in the standard. This suggestion did not meet with much favor in the committee but it helped to add impetus to a suggestion that a 3-day or a 4-day mortar test be considered. This question was referred to the Sub-Committee on Strength.

3. The Tentative Specifications and Tests for Compressive Strength of Portland Cement Mortars (C 9 – 16 T) have been given further serious consideration and the sub-committee has reviewed much available data but has finally concluded that more important

data must be secured before it can recommend the advancement to standard or before it can even recommend any modifications of the present tentative standard.

4. Suggestions that the chemical requirements for both sulfuric anhydride and magnesia could be changed have been referred to the Sub-Committee on Chemical Limitations, which has the changes under consideration.

5. A proposal that there again be added a specification requirement for the fineness on a No. 100 sieve has also been considered with the decision that such a requirement would not add to the value of the specifications. The Sub-Committee on Fineness has presented a report which is appended hereto.

Of minor questions there have been phases of methods which were submitted for consideration or interpretation. Some slight changes in phraseology would take care of these questions but they will be explained more readily in the Manual hereinafter referred to.

For some time a sub-committee has been at work compiling a laboratory Manual which is intended to serve as a supplement to the Standard Specifications and Tests in that it will present interpretation of both the requirements and the methods of tests and will also emphasize some portions of both which may not be fully appreciated by the users of either. By means of this Manual, it is believed that some clauses of the standard specifications will be more clearly understood, with a resulting greater uniformity in results of tests—especially as between results secured in different laboratories. This greater uniformity will overcome some of the objections which some may seemingly have to some portions of the standard. This Manual will be published later.

Practically all of this report to this point has dealt with specifications and tests for portland cement but this does not mean that the committee has not been cognizant of a growing interest in the older and newer types of hydraulic cements. In order to be able to present and to conduct proper lines for the best study of these types of cement, a sub-committee has been formed. This sub-committee has effected organization and has been busy in preparing a program which will soon be presented. Such action is very timely and will undoubtedly prove of great value in helping to spread information at a time when information about cements is much desired.

The Sub-Committee on Strength has outlined a series of mortar tests in which three forms of test pieces using different proportions, consistencies and ages are compared with the standard briquette, the purpose being to obtain additional data for their studies of cement mortars in compression and upon the possibility of a short-time strength test on mortar. Each of the laboratories listed below is carrying out this series and the committee wishes to take this occasion of thanking them for their valued cooperation:

Atlas Portland Cement Co.;
Bureau of Public Roads;
Bureau of Standards;
Canada Cement Co.;
Clinchfield Portland Cement Co.;
E. L. Conwell and Co.;
Department of State Engineer and Surveyor (New York);
Department of Public Works (Canada);
Dixie Portland Cement Co.;
Froehling and Robertson;
Hydro-Electric Power Commission of Ontario;
Illinois State Highway Department;
Lehigh Portland Cement Co.;
Michigan State Highway Department;
New Hampshire State Highway Department;
New Jersey State Highway Department;
Pennsylvania State Highway Department;
Portland Cement Association;
Thompson and Lichtner;
West Virginia State Highway Department.

This report has been submitted to letter ballot of the committee, which consists of 56 members, of whom 40 have voted affirmatively, none negatively, and 16 have refrained from voting.

Respectfully submitted on behalf of the committee,

RUSSELL S. GREENMAN,
Chairman.

R. B. YOUNG,
Secretary.

REPORT OF SUB-COMMITTEE III ON FINENESS

THE PROPOSED RESTORATION OF A NO. 100 SIEVE REQUIREMENT TO THE STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

The occasion of this report is made clear in the following letter to the members of Sub-Committee III written by the chairman of the sub-committee under date of December 21, 1923:

MEMBERS OF SUB-COMMITTEE III,
COMMITTEE C-1, A.S.T.M.

Gentlemen:

At the June, 1923, meeting of Committee C-1, Mr. Webster asked the committee to consider restoring to the cement specifications a fineness requirement on the No. 100 sieve. He stated that the residue on the No. 200 sieve could be, and often was, objectionably coarse.

This matter was referred to Sub-Committee III for study and report.

Under date of August 27, 1923, I wrote to Mr. Webster as follows:

"Before taking this question up with the members of the sub-committee, I should appreciate having a statement from you setting forth the conditions which have come to your attention giving rise to this question, in order to enable me to present the matter clearly to the sub-committee.

"I believe it would be desirable to furnish specific data in so far as possible, such as are suggested by the following questions:

1. In how many instances have you noted an abnormally coarse residue on the No. 200 sieve?
2. How many samples have been tested and shown to have more than 7 or 8 per cent residue on the No. 100 sieve, at the same time meeting the No. 200 sieve requirement?
3. How many and what brands or mills have apparently been abnormal in respect to gradation of coarse particles in the cement?
4. Is there evidence of deliberate adulteration of the cement by the addition of coarse material?

"I believe this will indicate sufficiently well the sort of evidence I should like to present to the sub-committee."

Mr. Webster replied to the foregoing letter under date of October 27, 1923, stating that the Assistant Testing Engineer of the Bureau of Surveys, Philadelphia, was sending the data required. Mr. Webster also said:

"I do not think, however, that the question of the name of the cement which contained in the residue on the 200 sieve very coarse material nor the number of times that such cement was shipped to the work enters materially into the question which I raised at the meeting of Committee C-1 at Atlantic City June last.

"The fact that it is possible under the present standard specifications to ship to the work material containing very coarse particles in the residue on the 200 sieve shows that the specifications are at fault and that the weak spot in them should be remedied. That is, that there should be a requirement for the use of a No. 50 or No. 100 sieve."

The following excerpt from the Assistant Testing Engineer's letter of October 24, 1923, covers the essential points in his report:

"During July, August and September, 1921, the Grade Crossing Division of the Bureau of Surveys was doing work known as the opening of Tulip Street.

"On five carload shipments during that period we noticed considerable coarse material, unground clinker, ranging in size from small bird shot up to the size of a pea. The total sample was sieved through the 50-mesh sieve and the percentage of coarse material obtained in this manner ranged from 0.1 to 6.4 per cent.

"The sample after being freed of this coarse material was then used for the regular tests which we make on portland cement, and there was nothing wrong with these samples used in such a manner, excepting that I noted a slight decrease in strength at the end of the six months' period on a few of the samples.

"The matter was called to the attention of the cement people when we first noticed it, and after some parleys they took the attitude that we had no legitimate kick as long as the material submitted fulfilled the standard A.S.T.M. specifications. We could not see their point of view, however, and had to place them on the 28-day waiting list instead of allowing the immediate use of the cement, as we do with all standard brands, providing they keep up to the standard specifications. We are making tests on all these brands regularly.

"The 28-day waiting list enabled them to see the matter from our viewpoint. The fault was corrected and we have had no trouble since, but found out afterwards that the matter was rank carelessness due to some laborers shoveling coarse tailing back into the cement stream when it proceeded to the loading machine. I am sending you copies of these tests."

The following test data accompanied the foregoing letter.

	Residue on No. 50 Sieve, per cent	Fineness after Discarding Material Retained on No. 50 Sieve, per cent	
		No. 100	No. 200
No. 5609	6.4	3.0	17.0
No. 5741	0.6	1.0	10.0
No. 5742	0.5	1.0	11.0
No. 5743	1.3	1.4	13.2
No. 5794	0.1	1.0	11.4

In acknowledging the receipt of the foregoing data I requested the Assistant Testing Engineer to confirm my understanding that sample No. 5609 was an unique case and probably to be classed as an accidental condition. This he did, but stated that in tests of 18 brands of cement during 1922, the average residues on the No. 100 sieve varied from 0.6 to 3.1 per cent for the different brands, and that in some cases, at least, the consumer was paying for a considerable percentage of needlessly coarse material, with no recourse under the present specifications.

It is for our sub-committee to decide whether this question is sufficiently important to warrant an investigation of the real need for a fineness limitation on the No. 100 sieve, and if so, to conduct such an investigation with a view to obtaining the data on which a recommendation may be made to the parent committee. If the committee does not consider the matter of sufficient importance to warrant reopening this question, it should so report.

I should like to have your opinion on this question, and also whether in your experience cases have occurred in which cement meeting the present fineness requirements on the No. 200 sieve shows an undesirable or an unusual amount of coarse material.

In view of the fact that a meeting of Committee C-1 will probably be held in January, a prompt reply will be appreciated.

Yours very truly,
(Signed) J. C. PEARSON,
Chairman, Sub-Committee III.

Replies to the foregoing letter were received from eight members of the sub-committee. It is significant that not one of these was in favor of restoring a No. 100 sieve requirement to the cement specification, and seven were positively opposed to it.

As the replies from the sub-committee members covered the outstanding objections, a collective summary of them is here given.

All replies were unanimous in indicating that an objectionably coarse residue on the No. 200 sieve was very rarely encountered, that it may occur sometimes from accidental causes, and if so, can be rectified without recourse to specifications, and that an additional fineness requirement is neither desirable nor necessary. Several called attention to the fact that of the five samples reported by the Philadelphia laboratory, the one which showed an unduly large residue on the No. 50 and No. 100 sieves would have been rejected by the No. 200 sieve requirement and all of the others would have met a requirement of 97 per cent passing the No. 100 sieve. One member, who was familiar with the circumstances in the Philadelphia case, said that only in the case of cements of low tensile strength would the coarse residue have a serious effect, but another commented on the general belief that material retained on the No. 200 sieve is inert and, if this No. 200 residue is within the prescribed limits, its relative coarseness is immaterial.

In conclusion, it is the opinion of the sub-committee that restoration of the No. 100 sieve fineness requirement to the cement specifications is not warranted by the evidence presented, and it recommends that no change be made in the specifications.

The sub-committee consists of ten members, of whom nine have voted affirmatively in approval of this report, none negatively, and one has not voted.

Respectfully submitted on behalf of the sub-committee,

J. C. PEARSON,
Chairman.

REPORT OF COMMITTEE C-2
ON
REINFORCED CONCRETE

A majority of the members of Committee C-2 on Reinforced Concrete are members of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, which latter committee has been actively engaged during the year in the revision of its Tentative Specifications for Concrete and Reinforced Concrete. These members of Committee C-2 have attended the meetings of the Joint Committee and of its several sub-committees of which they are also members.

The Joint Committee's second report transmitting Standard Specifications for Concrete and Reinforced Concrete will be presented at the annual meeting of the Society. Inasmuch as this is a subject in which Committee C-2 is vitally interested and since so large a proportion of its members have been active in the work of the Joint Committee it has not seemed desirable for the committee to further burden these members by its meetings. The work of the Joint Committee is in the field of activity of Committee C-2 and it is the latter's intention to supplement the work of the Joint Committee.

The committee has not reached final conclusions as to its Tentative Rules for the Inspection of Concrete and Reinforced Concrete Work and accordingly recommends that these remain tentative for another year.

Respectfully submitted on behalf of the committee,

RICHARD L. HUMPHREY,
Chairman.

S. C. HOLLISTER,
Secretary.

REPORT
OF THE
JOINT COMMITTEE ON STANDARD SPECIFICATIONS
FOR
CONCRETE AND REINFORCED CONCRETE

SUBMITTING
STANDARD SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

Affiliated Committees

OF THE

American Society of Civil Engineers
American Society for Testing Materials
American Railway Engineering Association
American Concrete Institute
Portland Cement Association

Submitted to Constituent Organizations
August 14, 1924

PREFACE.

The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete consists of five representatives from each of the following:

American Society of Civil Engineers,
American Society for Testing Materials,
American Railway Engineering Association,
American Concrete Institute,
Portland Cement Association.

This Committee is the successor of the Joint Committee on Concrete and Reinforced Concrete which was organized in Atlantic City, N. J., June 17, 1904, and was formed by the union of special committees appointed in 1903 and 1904 by the above-named organizations, except the American Concrete Institute which was added by invitation of the Joint Committee in 1915. The previous Committee presented progress reports in 1909 and 1912 and adopted a final report to its constituent organizations on July 1, 1916. It was the purpose of that Committee to prepare a Recommended Practice for Concrete and Reinforced Concrete. Its final report stated:

"The report is not a specification but may be used as a basis for specifications."

The present Joint Committee is charged with the preparation of Specifications for Concrete and Reinforced Concrete and in preparing these specifications is using as a basis the report of the former Joint Committee with such modifications as are necessary to make its recommendations agree with current practice, and such new data as mark advances in the art.

The initiative in bringing about the present Joint Committee was taken by the Committee on Reinforced Concrete of the American Society for Testing Materials on June 27, 1917, when the committee voted to request the Executive Committee of the Society to invite the Member-Societies of the previous Joint Committee to cooperate in the formation of a new Joint Committee. The Executive Committee approved this request on April 25, 1919, and an invitation was issued to each of the above-named organizations by the Executive Committee on behalf of the American Society for Testing Materials, to appoint five members on a Joint Committee on Specifications for Reinforced Concrete. The last of these organizations accepted the invitation on November 22, 1919. On January 21, 1920, a call for an organizing meeting on February 11, 1920, was sent by the Executive Committee of that Society to each of the twenty-five representatives of cooperating organizations, together with a list of members of the Joint Committee, and an outline of organization that had been previously submitted by the American Society for Testing Materials to and approved by the cooperating organizations.

The organizing meeting was held at the Engineers' Club, Philadelphia, Pa., and was called to order by George S. Webster, then Vice-President of the American Society for Testing Materials, who explained that he had been directed by the Executive Committee of that Society to act as Temporary Chairman; he further stated that C. L. Warwick, Secretary-Treasurer of the Society, had been requested to act as Temporary Secretary until a formal organization of the Joint Committee had been effected.

The personnel of the Joint Committee is as follows:

American Society of Civil Engineers.

W. A. Slater, *Chairman*,
Engineer-Physicist, Bureau of Standards, Washington, D. C.
Milton H. Freeman, Division Engineer,
N. Y. and N. J. Bridge and Tunnel Commission, New York City.
Appointed June 20, 1922, to fill vacancy.
A. E. Lindau, President, American Wire Fence Co., Chicago, Ill.
Franklin R. McMillan, Consulting Engineer,
628 Metropolitan Bank Building, Minneapolis, Minn.
Appointed June 6, 1921, to fill vacancy.
Sanford E. Thompson, Consulting Engineer,
The Thompson and Lichtner Company, 136 Federal Street, Boston, Mass.
William K. Hatt, Professor of Civil Engineering,
Purdue University, Lafayette, Ind.
Resigned April 3, 1922.
Rudolph P. Miller,
Consulting Engineer, New York City.
Resigned April 25, 1921. Succeeded as Chairman by W. A. Slater.

American Society for Testing Materials.

Richard L. Humphrey, *Chairman*,
Consulting Engineer, Philadelphia, Pa.
Albert T. Goldbeck, Chief, Division of Tests,
Bureau of Public Roads, Washington, D. C.
Edward E. Hughes, Vice-President,
Franklin Steel Works, Franklin, Pa.
Henry H. Quimby, Consulting Engineer,
Philadelphia, Pa.
Leon S. Moisseiff, Engineer of Design,
Delaware River Bridge, Brooklyn, N. Y.

American Railway Engineering Association.[1]

J. J. Yates, *Chairman*,
Bridge Engineer, Central Railroad of New Jersey, Jersey City, N. J.
T. L. D. Hadwen, Engineer of Masonry Construction,
Chicago, Milwaukee and St. Paul Ry., Chicago, Ill.
Appointed November 21, 1921, to fill vacancy.
Frederick E. Schall, Bridge Engineer,
Lehigh Valley Railroad, Bethlehem, Pa.
C. C. Westfall, Engineer of Bridges,
Illinois Central Railroad Company, Chicago, Ill.
George E. Boyd, Formerly Division Engineer,
Delaware, Lackawanna and Western R. R., Buffalo, N. Y.
Resigned November 7, 1921.
H. T. Welty, Engineer of Structures,
New York Central Railroad, New York City.
Resigned December 27, 1922.

American Concrete Institute.[1]

S. C. Hollister, *Chairman*,
Consulting Engineer, Philadelphia, Pa.
Robert W. Lesley, Past-President, Portland Cement Association,
Philadelphia, Pa.
Angus B. MacMillan, Chief Engineer,
Aberthaw Construction Company, Boston, Mass.
Appointed October 19, 1920, to fill vacancy.
Egbert J. Moore, Vice-President,
Turner Construction Company, New York City.
Arthur R. Lord, President,
Lord Engineering Co., Chicago, Ill.
Resigned April 17, 1923.
Leonard C. Wason, President,
Aberthaw Construction Company, Boston, Mass.
Resigned October 19, 1920.

Portland Cement Association.

Frederick W. Kelley, *Chairman*,
President, Portland Cement Association, Albany, N. Y.
Duff A. Abrams, Professor in Charge,
Structural Materials Research Laboratory, Lewis Institute, Chicago, Ill.
Ernest Ashton, Chemical Engineer,
Lehigh Portland Cement Company, Allentown, Pa.
Edward D. Boyer, Cement Expert,
Atlas Portland Cement Company, New York City.
A. C. Irwin, Engineer, Structural Bureau,
Portland Cement Association, Chicago, Ill.
Appointed September 29, 1922, to fill vacancy.
J. E. Freeman, Formerly Manager, Structural Bureau,
Portland Cement Association, Chicago, Ill.
Appointed January 1, 1921, to fill vacancy.
Resigned September 14, 1922.
J. H. Libberton, Formerly Manager, Service Bureau,
Universal Portland Cement Company, Chicago, Ill.
Resigned December 31, 1920.

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[1] At the time of the completion of this report a vacancy existed in the representation of both the American Railway Engineering Association and the American Concrete Institute.

ORGANIZATION OF JOINT COMMITTEE

The Committee perfected a permanent organization on February 11, 1920, under the title "Joint Committee on Standard Specifications for Concrete and Reinforced Concrete" with the following officers:

Chairman, Richard L. Humphrey, Philadelphia, Pa.,
Vice-Chairman, J. J. Yates, Jersey City, N. J.,
Secretary-Treasurer, Duff A. Abrams, Chicago, Ill.,

and an Executive Committee consisting of these officers, and Rudolph P. Miller,[1] New York City, and S. C. Hollister, Philadelphia.

The Committee adopted Rules of Organization and apportioned the work of preparing the Specifications among sub-committees with the following personnel:

1. *Materials (other than Reinforcing).*
   - Albert T. Goldbeck, *Chairman*
   - Duff A. Abrams
   - Sanford E. Thompson
   - J. J. Yates
   - J. E. Freeman[2]
   - J. H. Libberton[3]
2. *Metal Reinforcement.*
   - J. J. Yates, *Chairman*
   - Duff A. Abrams
   - Edward E. Hughes
   - A. E. Lindau
   - W. K. Hatt[4]
   - Arthur R. Lord[5]
3. *Proportioning and Mixing.*
   - W. A. Slater, *Chairman*
   - Duff A. Abrams
   - Ernest Ashton
   - T. L. D. Hadwen
   - Henry H. Quimby
   - George E. Boyd[6]
4. *Forms and Placing*
   - T. L. D. Hadwen, *Chairman*
   - Edward D. Boyer
   - Angus B. MacMillan
   - Egbert J. Moore
   - Frederick E. Schall
   - George E. Boyd,[6] *Formerly Chairman*
   - Leonard C. Wason[7]
5. *Design.*
   - S. C. Hollister, *Chairman*
   - A. C. Irwin
   - A. E. Lindau
   - Franklin R. McMillan
   - Egbert J. Moore
   - W. A. Slater
   - W. K. Hatt[4]
   - Arthur R. Lord[5]
   - H. T. Welty[8]
6. *Details of Construction and Fireproofing.*
   - Franklin R. McMillan, *Chairman*
   - M. H. Freeman
   - Leon S. Moisseiff
   - C. C. Westfall
   - Rudolph P. Miller,[9] *Formerly Chairman*
   - W. K. Hatt[4]
   - Arthur R. Lord[5]

---

[1] Succeeded by W. A. Slater, May 25, 1921.

[2] Resigned September 14, 1922.

[3] Succeeded by J. E. Freeman, January 1, 1921.

[4] Resigned April 3, 1922.

[5] Resigned April 17, 1923.

[6] Succeeded by T. L. D. Hadwen, November 21, 1921.

[7] Succeeded by Angus B. MacMillan, October 19, 1920.

[8] Resigned December 27, 1922.

[9] Succeeded by Franklin R. McMillan, June 6, 1921.

7. *Waterproofing and Protective Treatment.*
   Frederick W. Kelley, *Chairman*
   Albert T. Goldbeck
   S. C. Hollister
   Robert W. Lesley
   C. C. Westfall

8. *Surface Finish.*
   Henry H. Quimby, *Chairman*
   Edward D. Boyer
   A. C. Irwin
   Angus B. MacMillan
   J. E. Freeman[1]
   J. H. Libberton[2]
   Leonard C. Wason[3]
   H. T. Welty[4]

9. *Form of Specifications.*
   Richard L. Humphrey, *Chairman*
   Duff A. Abrams, *Secretary*
   T. L. D. Hadwen
   Albert T. Goldbeck
   S. C. Hollister
   Frederick W. Kelley
   Franklin R. McMillan
   Henry H. Quimby
   W. A. Slater
   J. J. Yates
   George E. Boyd[5]
   Rudolph P. Miller[6]

MEETINGS

The Joint Committee held the following meetings:

1920

Organization meeting, Philadelphia, February 11.
Second meeting, Asbury Park, N. J., June 23 and 24.
Third meeting, New York City, October 26, 27, and 28.
Fourth meeting, New York City, December 15, 16, and 17.

1921

Fifth meeting, New York City, March 2, 3, and 4.
Sixth meeting, New York City, April 13, 14, and 15.
Seventh meeting, Asbury Park, N. J., June 21.
Eighth meeting, New York City, October 4 and 5.
Ninth meeting, New York City, December 9.

1922

Tenth meeting, Cleveland, February 17.
Eleventh meeting, Philadelphia, June 1 and 2.
Twelfth meeting, Philadelphia, September 19.
Thirteenth meeting, New York City, October 30 and 31.

---

[1] Resigned September 14, 1922.
[2] Succeeded by J. E. Freeman, January 1, 1921.
[3] Succeeded by Angus B. MacMillan, October 19, 1920.
[4] Resigned December 27, 1922.
[5] Succeeded by T. L. D. Hadwen, November 21, 1921.
[6] Succeeded by Franklin R. McMillan, June 6, 1921.

1923

Fourteenth meeting, Cincinnati, January 25 and 26.
Fifteenth meeting, New York City, March 28.
Sixteenth meeting, New York City, June 6.
Seventeenth meeting, New York City, October 3, 4, and 5.
Eighteenth meeting, New York City, December 12, 13, and 14.

Numerous meetings of sub-committees were held during the intervals between the meetings of the Joint Committee.

At these meetings the Joint Committee considered the reports of its sub-committees, which were edited by the Sub-Committee on Form and incorporated in the Standard Specifications for Concrete and Reinforced Concrete herewith submitted.

TENTATIVE REPORT SUBMITTED FOR CRITICISM AND DISCUSSION

The Joint Committee submitted to its constituent organizations Tentative Specifications for Concrete and Reinforced Concrete, June 4, 1921. As provided in its Rules of Organization, these Specifications have been open for criticism and discussion by the constituent organizations for a period of more than two years.

These specifications were discussed:

1. At a two-day meeting of the American Society of Civil Engineers, New York City, covering six sessions on December 7 and 8 1921, which discussion was continued for six months in the Society Proceedings;
2. At the Annual Convention of the American Concrete Institute, Cleveland, February 15, 1922;
3. The American Railway Engineering Association referred the Specifications to its Committee on Masonry and the latter discussed them at several of its meetings;
4. The American Society for Testing Materials referred the Specifications to its several committees who were particularly interested and they were discussed at the annual meeting of the Society held at Atlantic City, N. J., June 27–30, 1922.
5. The Portland Cement Association referred them to its Committee on Technical Problems.

FIELD TESTS OF CONCRETE

As a result of the discussion and criticisms the Joint Committee agreed to sponsor a series of field tests made under the auspices of a Joint Committee of Contractors, on which the Associated General Contractors of America were represented, with the object of determining whether the recommendations of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete were practical, especially as regards the provisions for the control of the quality of the concrete in the field.

Tests were made during the summer of 1923 on the concrete used in the construction of Building No. 10 of the Victor Talking Machine Company, Camden, N. J., through the cooperation of the owner and of Stone and Webster, Inc., the contractors; these tests have been completed and with a discussion of the results will be available in the near future.

A second series of tests were made of the concrete being used in the construction of the piers of the Newark Bay Bridge of the Central Railroad of New Jersey through the cooperation of the Railroad Company; these tests are practically completed; it is expected that other tests will be made during the present year.

All of these tests have been made possible through the cooperation of the owners of the structures at which the tests were made, the U. S. Department of Commerce (Bureau of Standards), Department of Highways of the Commonwealth of Pennsylvania, the Joint Committee of Contractors, and the Structural Materials Research Laboratory, Lewis Institute, to whom the thanks and appreciation of the Joint Committee are extended.[1]

The results thus far obtained are a substantial justification of the Joint Committee's recommendations.

Another series of tests is to be inaugurated under the auspices of the Joint Committee on Concrete Reinforcement of the American Society for Testing Materials, having as an object the development of data as a basis for specifications for metal reinforcement.

STANDARD SPECIFICATIONS

The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete has carefully reviewed the criticisms and discussions of its recommendations and the data that have become available since it submitted the Tentative Specifications in 1921, and has made such modifications in the Specifications as were desirable.

The Committee is of the opinion that it should now submit the Standard Specifications for Concrete and Reinforced Concrete; with the later data as the result of tests now in progress it may be deemed desirable to submit revisions in the light of the information obtained.

The Committee in submitting the Specifications directs attention to the fact that while the Specifications are complete as regards the general uses of concrete and reinforced concrete, they may require some additional paragraphs to cover the use of these materials for special purposes.

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[1] For the Report on the Camden and Newark Bay Tests, see *Proceedings*, Am. Soc. Civil Engrs., January, 1925.

The Committee has under consideration supplementary specifications covering special uses of concrete and reinforced concrete on which it is not prepared to report at this time.

The Joint Committee further calls attention to the fact that it has undertaken to prepare specifications covering the fundamentals to be observed in the general use of concrete and reinforced concrete; no attempt has been made to cover the details involved in the use of these materials in special structures. Although the sections relating to design deal primarily with building construction, nevertheless the principles involved are of general application to structures of other types.

This report has been submitted to letter ballot of the Joint Committee which consists of 23 members,[1] representing the five societies, 22 of whom have voted affirmatively, none negatively, and one has refrained from voting.

Respectfully submitted,

RICHARD L. HUMPHREY, *Chairman.*

J. J. YATES, *Vice-Chairman*
ERNEST ASHTON
EDWARD D. BOYER
MILTON H. FREEMAN
ALBERT T. GOLDBECK
T. L. D. HADWEN
S. C. HOLLISTER
EDWARD E. HUGHES
A. C. IRWIN
FREDERICK W. KELLEY
ROBERT W. LESLEY

DUFF A. ABRAMS, *Secretary-Treasurer*
A. E. LINDAU
ANGUS B. MACMILLAN
FRANKLIN R. MCMILLAN
LEON S. MOISSEIFF
EGBERT J. MOORE
HENRY H. QUIMBY
FREDERICK E. SCHALL
W. A. SLATER
SANFORD E. THOMPSON

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[1] At the time of the completion of this report a vacancy existed in the representation of both the American Railway Engineering Association and the American Concrete Institute.

STANDARD SPECIFICATIONS
FOR
CONCRETE AND REINFORCED CONCRETE

Submitted by the
JOINT COMMITTEE ON STANDARD SPECIFICATIONS
FOR CONCRETE AND REINFORCED CONCRETE

Affiliated Committees
OF THE
American Society of Civil Engineers
American Society for Testing Materials
American Railway Engineering Association
American Concrete Institute
Portland Cement Association

August 14, 1924

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LIST OF APPENDICES

The Mandatory Appendices 1 to 15, inclusive, consisting of Notation, Figures, Specifications and Methods of Tests, form a part of the Standard Specifications for Concrete and Reinforced Concrete. Advisory Appendices 16, 17 and 18 are for information only.

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2. Standard Specifications and Tests for Portland Cement (C 9 – 21)[2] ...
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7. Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (A 82 – 21 T)[3] ....
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9. Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 22 T)[4] ....
10. Standard Method of Test for Organic Impurities in Sands for Concrete (C 40 – 22)[2] ....
11. Tentative Method of Test for Consistency of Portland-Cement Concrete for Pavements or for Pavement Base (D 138 – 22 T)[4] ....
12. Tentative Methods of Making Compression Tests of Concrete (C 39 – 21 T)[3] ....
13. Standard Methods of Making and Storing Specimens of Concrete in the Field (C 31 – 21)[2] ....
14. Standard Specifications for Cast-Iron Pipe and Special Castings (A 44 – 04)[2] ....
15. Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 21)[2] ....

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17. Effect of Oils and Miscellaneous Liquids on Concrete and Method of Protective Treatment where Required 381
18. Supervision and Inspection of Concrete Construction 384

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[1] The Standard and Tentative Specifications and Methods of Tests are those of the American Society for Testing Materials. They are not reprinted here but appear in the publications of the Society as indicated in the footnote reference to the individual specifications.

[2] 1924 Book of A.S.T.M. Standards.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 21 (1921); also 1924 Book of A.S.T.M. Tentative Standards.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I (1922); also 1924 Book of A.S.T.M. Tentative Standards.

STANDARD SPECIFICATIONS
FOR
CONCRETE AND REINFORCED CONCRETE.

CHAPTER I. GENERAL INSTRUCTIONS.

General Instructions.

1. These Specifications cover the general conditions affecting the use of concrete and reinforced concrete. To use them in connection with the contract it will be necessary for the Engineer to:

(*a*) Provide the detail specifications covering the work in particular in which the concrete and reinforced concrete are to be used;

(*b*) Section 7, Table I, insert percentages required;

(*c*) Section 10, fill blank indicating percentage of mortar strength required of fine aggregate as compared with standard Ottawa sand;

(*d*) Section 14, Table II, insert sieve sizes and percentages required;

(*e*) Section 21, strike out one of the titles of specifications for reinforcement bars; if billet-steel bars are to be used, indicate whether structural, intermediate or hard grade.

(*f*) Section 24, strike out one of the titles of specifications for structural steel shapes;

(*g*) Section 28, strike out "volume" or "weight;"

(*h*) Section 29, if no tests of concrete are to be made, strike out last paragraph in accordance with footnote. Table IV, insert the concrete strengths which are assumed as basis for design of the different portions of the work;

(*i*) Section 30, Table V, insert the slumps required;

(*j*) Section 51, strike out the method or methods for depositing concrete under water which are not applicable to the work;

(*k*) Chapter X, strike out sections on surface finish which do not apply;

(*l*) Section 95, strike out one of the two sections on terrazzo finish.

CHAPTER II. DEFINITIONS.

Definitions.

2. The following definitions give the meaning of certain terms as used in these specifications:

Acid Proofing.—Treatment of a concrete surface in order to provide resistance to the action of acids.

Aggregate.—Inert material which is mixed with portland cement and water to produce concrete; in general, aggregate consists of sand, pebbles, gravel, crushed stone, or similar materials. (See *Fine Aggregate, Coarse Aggregate.*)

Anchorage.—The embedment in concrete of a portion of a reinforcement bar, either straight or with hooks, designed to prevent pulling out or slipping of the bar when subjected to stress. (The anchorage of tension reinforcement in beams includes only the embedded length beyond a point of contra-flexure or of zero moment.)

Approved.—Meeting the approval of, or specifically authorized by, the Engineer.

Buttressed Retaining Wall.—A retaining wall with brackets or buttresses on the side opposite the pressure face uniting the upright section with the toe of the base.

Cantilever Retaining Wall.—A reinforced concrete wall having an upright section and a base, each of which resists by cantilever action the pressure to which it is subjected.

Cellular Retaining Wall.—A retaining wall with a base, longitudinal upright sections, and a series of transverse walls, dividing the space between the longitudinal sections into cells which are filled with earth or other suitable material.

Coarse Aggregate.—Aggregate, subject to specified tolerances, retained on a No. 4 sieve and of a maximum size generally not larger than 3 in. (See *Aggregate, Fine Aggregate.*)

Column.—An upright compression member the length of which exceeds three times its least lateral dimension.

Column Capital.—An enlargement of the upper end of a reinforced concrete column designed and built to act as a unit with the column and flat slab.

Column Strip.—A portion of a panel of a flat slab which has a uniform width equal to one-fourth of the panel length perpendicular to the direction of the strip, and the outer edge of which lies on the edges of the panel. (See *Middle Strip;* also Appendix 1, Fig. 15.)

Composite Column.—A circumferentially reinforced concrete column with a core of structural steel or cast iron which is designed to carry a portion of the load.

Concrete.—A mixture of portland cement, fine aggregate, coarse aggregate and water. (See *Mortar.*)

Consistency.—A general term used to designate the relative plasticity of freshly mixed concrete or mortar.

Counterforted Retaining Wall.—A reinforced concrete wall with brackets or counterforts on the pressure face uniting the upright section to the heel of the base.

Crusher-Run Stone. — Unscreened crushed stone. (See *Stone Screenings.*

Cyclopean Concrete.—Concrete in which stones weighing more than 100 lb. are individually embedded.

Dead Load.—The weight of the permanent parts of the structure.

Deformed Bar.—Reinforcement bar with shoulders, lugs, or projections formed integrally with the bar during rolling.

Diagonal Direction.—A direction parallel or approximately parallel to the diagonal of the panel of a flat slab.

Dropped Panel.—The structural portion of a flat slab which is thickened throughout an area surrounding the column capital.

Effective Area of Concrete.—The area of a section of the concrete which lies between the tension reinforcement and the compression surface in a beam or slab.

Effective Area of Reinforcement.—The area obtained by multiplying the right cross-sectional area of the metal reinforcement by the cosine of the angle between its direction and that for which the effectiveness of the reinforcement is to be determined.

Engineer.—The engineer in responsible charge of the work.

Fine Aggregate.—Aggregate, subject to specified tolerances, passing through a No. 4 sieve. (See *Aggregate, Coarse Aggregate.*)

Flat Slab.—A concrete slab having reinforcement bars extending in two or more directions without beams or girders to carry the load to supporting members.

Footing.—A structural unit used to distribute wall or column loads to the foundation materials.

Gravel.—Rounded particles larger than sand resulting from the natural disintegration of rocks. (See *Sand.*)

Laitance.—Extremely fine material of little or no hardness which may collect on the surface of freshly-deposited concrete or mortar, resulting from the use of excess mixing water, and usually recognized by its relatively light color.

Live Load.—Loads and forces other than the dead load.

Middle Strip.—The portion of a panel of a flat slab which extends in a direction parallel to a side of the panel, the width of which is one-half the panel length at right angles to the direction of the strip and whose center line lies on the center line of the panel. (See *Column Strip;* also Appendix 1, Fig. 15.)

Mortar.—A mixture of portland cement, fine aggregate and water. (See *Concrete.*)

Negative Reinforcement.—Reinforcement so placed as to take tensile stress due to negative bending moment.

Oilproofing.—Treatment of a concrete surface for the purpose of preventing the penetration of, and resisting the action of, oils.

Panel Length.—The distance in either rectangular direction between centers of two columns of a panel.

Pedestal.—An upright compression member whose height does not exceed three times its least lateral dimension.

Pedestal Footing.—A column footing projecting less than one-half its depth from the faces of the column on all sides and having a depth not more than three times its least width.

Plain Concrete.—Concrete without metal reinforcement.

Portland Cement.—The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

Positive Reinforcement.—Reinforcement so placed as to take tensile stress due to positive bending moment.

Principal Design Section.—The vertical sections in a flat slab on which the moments in the rectangular directions are critical. (See Section 143.)

Ratio of Reinforcement.—The ratio of the effective area of the reinforcement cut by a section of a beam or slab to the effective area of the concrete cut by that section.

Rectangular Direction.—A direction parallel to a side of the panel of a flat slab.

Reinforced Concrete.—Concrete in which metal is embedded in such a manner that the two materials act together in resisting forces.

Rubble Aggregate.—Stone or gravel larger than 3 in. in diameter and weighing not more than 100 lb.

Rubble Concrete.—Concrete in which pieces of rubble aggregate are individually embedded. (See *Rubble Aggregate.*)

Sand.—Small grains resulting from the natural disintegration of rocks. (See *Gravel.*)

Screen.—A metal plate with closely spaced circular perforations. (See *Sieve.*)

Sieve.—Woven wire cloth with square openings. (See *Screen.*)

Slump.—The shortening of a standard test mass of freshly mixed concrete, used as a measure of workability in accordance with the standard method. (See Appendix 11.)

Standard Sand.—Natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve, used as the fine aggregate in standard strength tests of portland cement. (For specifications see Appendix 2.)

Stone Screenings.—Crushed stone, subject to specified tolerances, passing through a No. 4 sieve. (See *Crusher-Run Stone.*)

Strut.—A compression member other than a column or pedestal.

Tremie.—A water-tight pipe of suitable dimensions, generally used in a vertical position, for depositing concrete under water.

Wall Beam.—A reinforced concrete beam which extends from column to column along the outer edge of a wall panel.

CHAPTER III. QUALITY OF CONCRETE

Strength.

3. The design of the various portions of the structure is based on the assumption that the concrete will develop the compressive strength at 28 days which, for purposes of design only, are given in Section 29, Table IV.

Tests of Field Specimens.

4. The making, curing and testing of field concrete test specimens shall be carried out in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Serial Designation: C 31 – 21) of the American Society for Testing Materials. (Appendix 13.)

CHAPTER IV. MATERIALS.[1]

A. Portland Cement.

Portland Cement.

5. Portland cement shall conform to the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9 – 21) of the American Society for Testing Materials[2] (Appendix 2) and subsequent revisions thereof.

B. Fine Aggregate.

General Requirements.

6. Fine aggregate shall consist of sand or other approved inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

Grading.

7. Fine aggregate shall range in size from fine to coarse within the limits indicated in Table I.

TABLE I.—GRADING OF FINE AGGREGATE.

	PER CENT BY WEIGHT
Passing through No. 4 sieve	not less than (*a*)[3]
Passing through No. 50 sieve	not more than (*b*)[3] not less than (*c*)[3]
Weight removed by decantation	not more than (*d*)[3]

---

[1] These Specifications cover the usual requirements for aggregate. Where concrete having special properties is essential the specifications should make clear the characteristics of the aggregate to be used.

[2] These Specifications are also the standard of the following: United States Government, American Railway Engineering Association, American Concrete Institute, and Portland Cement Association. Approved by the American Engineering Standards Committee as an American Standard.

[3] The grading requirements will vary with the type of work and characteristics of materials available in any given locality. Wherever practicable the following values should be inserted: (*a*) = 85 per cent; (*b*) = 30 per cent; (*c*) = 10 per cent; (*d*) = 3 per cent.

Sieve Analysis. 8. The sieves and method of making sieve analysis shall conform to the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41 - 24) of the American Society for Testing Materials. (Appendix 8.)

Decantation Test. 9. The decantation test shall be made in accordance with the Tentative Method of Decantation Test for Sand and Other Fine Aggregates (Serial Designation: D 136 - 22 T) of the American Society for Testing Materials. (Appendix 9.)

Mortar Strength Test. 10. Fine aggregate shall be of such quality that mortar briquettes, cylinders or prisms, consisting of one part by weight of portland cement and three parts by weight of fine aggregate,[1] mixed and tested in accordance with the methods described in the Standard Specifications and Tests for Portland Cement (Appendix 2) will show a tensile or compressive strength at ages of 7 and 28 days not less than ...... per cent[2] of that of 1:3 standard Ottawa sand mortar of the same plasticity made with the same cement. Concrete tests shall be made in accordance with the Tentative Methods of Making Compression Tests of Concrete (Serial Designation: C 39 - 21 T) of the American Society for Testing Materials. (Appendix 12.)

Organic Impurities in Sand. 11. Sand, when tested in accordance with the Standard Method of Test for Organic Impurities in Sand for Concrete (Serial Designation: C 40 - 22) of the American Society for Testing Materials (Appendix 10), shall show a color not darker than the standard color unless it complies with Section 10.

Permissible Variations. 12. Fine aggregate which does not conform to the above requirements for grading, mortar strength or color, may be used only when approved by the Engineer and then in such proportions as he may require.

C. *Coarse Aggregate.*[3]

General Requirements. 13. Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Grading. 14. Coarse aggregate[4] shall range in size from fine to coarse within the limits given in Table II.

---

[1] In testing aggregate, care should be exercised to avoid the removal of any coating on the grains which may affect the strength. Sand should not be dried before being made into mortar, but should contain its natural moisture. The quantity of water contained may be determined on a separate sample and the weight of the sand used in the test corrected accordingly.

[2] This percentage must be inserted by the Engineer; it should preferably be 100.

[3] Appendix 16 furnishes a guide in determining the proportions of materials required to produce concrete of a given strength, using aggregates of different sizes and concrete of different consistencies.

[4] On work of considerable magnitude where several suitable coarse aggregates are available, an investigation of the relative economy of each is advisable.

TABLE II.—SIZE AND GRADING OF COARSE AGGREGATE.

PASSING	PER CENT BY WEIGHT
———[a] in. sieve (maximum size)	not less than 95
———[a] in. " (intermediate size)	not less than ——[a] not more than ——[a]
No. 4 "	not more than 10
No. 8 "	not more than 5

[a] The Engineer must insert in these blanks the sizes and percentages required with regard to materials available. The following table indicates desirable gradings for coarse aggregates of certain nominal maximum sizes:

Nominal Maximum Size of Aggregate, in.	Percentage by Weight Passing through Standard Sieves with Square Openings						Percentage Passing, not more than	
	3 in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	No. 4 Sieve	No. 8 Sieve
3	95	..	40-75	..	..	..	10	5
2	..	95	..	40-75	..	..	10	5
$1\frac{1}{2}$	..	..	95	..	40-75	..	10	5
1	..	..	..	95	..	..	10	5
$\frac{3}{4}$	..	..	..	..	95	..	10	5
$\frac{1}{2}$	..	..	..	..	..	95	10	5

Sieve Sizes.

15. The test for size and grading of aggregate shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete. (Appendix 8.)

Permissible Variations.

16. Coarse aggregate[1] which does not conform to the above requirements may be used only when approved by the Engineer and then in such proportions as he may require.

D. Rubble and Cyclopean Aggregate.

Rubble Aggregate.

17. Rubble aggregate shall consist of clean, hard, durable stone or gravel larger than 3 in. and weighing not more than 100 lb.

Cyclopean Aggregate.

18. Cyclopean aggregate shall consist of clean, hard, durable stone or gravel weighing more than 100 lb.

E. Storage of Aggregate.

Storage of Aggregate.

19. Aggregate shall be so stored as to avoid the inclusion of foreign materials. Frozen aggregate or aggregate containing lumps of frozen material shall be thawed before using.

F. Water.

General Requirements.

20. Water for concrete shall be clean and free from injurious amounts of oil, acid, alkali, organic matter, or other deleterious substance.

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[1] Requirements for the quality of coarse aggregate for special purposes should be inserted.

G. *Metal Reinforcement.*

Quality. 21. Metal reinforcement shall conform to the requirements of the Standard Specifications[1] for Billet-Steel Concrete Reinforcement Bars ...... grade (Serial Designation: A 15 – 14) of the American Society for Testing Materials (Appendix 3), Standard Specifications[1] for Rail-Steel Concrete Reinforcement Bars (Serial Designation: A 16 – 14) of the American Society for Testing Materials (Appendix 4), except that the provision for machining deformed bars before testing shall be eliminated.

Standard Sizes of Bars. 22. Reinforcement bars shall conform to the areas and equivalent sizes shown in Table III.

TABLE III.—SIZES AND AREAS OF REINFORCEMENT BARS.

Size of Bar, in.	Area, sq. in.	
	Round Bar	Square Bar
$\frac{3}{8}$	0.110	.....
$\frac{1}{2}$	0.196	0.250
$\frac{5}{8}$	0.306	.....
$\frac{3}{4}$	0.441	.....
$\frac{7}{8}$	0.601	.....
1	0.785	1.000
$1\frac{1}{8}$	.....	1.265
$1\frac{1}{4}$	.....	1.562

Deformed Bars. 23. An approved deformed bar shall be one that will develop a bond at least 25 per cent greater than that of a plain round bar of equivalent cross-sectional area.[2] The areas of deformed bars shall be determined by the minimum cross-section thereof.

Structural Shapes. 24. Structural steel shapes used for reinforcement shall conform to the requirements of the Standard Specifications[3] for Structural Steel for Bridges (Serial Designation: A 7 – 24) of the American Society for Testing Materials (Appendix 5), Standard Specifications[3] for Structural Steel for Buildings (Serial Designation: A 9 – 24) of the American Society for Testing Materials. (Appendix 6.)

Wire. 25. Wire for concrete reinforcement shall conform to the requirements of the Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (Serial Designation: A 82 – 21 T) of the American Society for Testing Materials. (Appendix 7.)

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[1] The engineer must strike out one of these titles. The Committee recommends as preferred material for reinforcement that meeting the requirements of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars of intermediate grade, made by the open-hearth process, except that the provision for machining the test specimens shall be eliminated.

[2] The Committee has under consideration a specification for deformed bars but is not prepared at this time to make more definite recommendations.

[3] The Engineer must strike out one of these titles.

Cast Iron.

26. Cast iron used in composite columns shall conform to the requirements of the Standard Specifications for Cast-Iron Pipe and Special Castings (Serial Designation: A 44 - 04) of the American Society for Testing Materials. (Appendix 14.)

CHAPTER V. PROPORTIONING AND MIXING CONCRETE

A. Proportioning.

Unit of Measure.

27. The unit of measure shall be the cubic foot. Ninety-four pounds of cement (one bag or $\frac{1}{4}$ bbl.) shall be considered as one cubic foot.

Measurement of Aggregates.

28. The method of measurement shall be such as to secure the specified proportions in each batch. The aggregates shall be measured separately by volume,[1] weight.[1] In volume measurement the fine aggregate and the coarse aggregate shall be measured loose, as thrown into the measuring device, and struck off.[2] The water shall be so measured as to insure the desired quantity in successive batches.

TABLE IV.—PROPORTIONS FOR CONCRETE.[a]

Part of Structure	Proportions by Volume			Concrete Strength[b] Assumed as Basis for Design, lb. per sq. in at 28 Days
	Cement	Fine Aggregate	Coarse Aggregate	
Footings	..	..	..	..[c]
Beams, Girders, Slabs	..	..	..	..
Columns	..	..	..	..
....	..	..	..	..
....	..	..	..	..
....	..	..	..	..

[a] The Engineer should determine, by tests of the available aggregate in advance of use, the proportions necessary to produce concrete of the required strength. Where this is impracticable Appendix 16 may be used as a guide. Appendix 16 is based on volumes of dry aggregate compacted by rodding in the measure, as specified in the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29 - 21) of the American Society for Testing Materials. (See Appendix 15.) Corrections should be made in the quantities in Appendix 16 to take account of the bulking effect of moisture in the fine aggregate. The bulking of fine aggregate (swelling) due to contained moisture, and the method of placing it in the measure, may result in a reduction of 25 per cent in the actual quantity of fine aggregate, as compared with that obtained by dry measurement by the standard method.

[b] The measure of the quality of concrete is its workability, as determined by the slump test or other approved test, and its compressive strength at 28 days, using the materials in the proportions specified.

[c] Concrete strengths to be used as basis for design shall be filled in by the Engineer.

Proportions.

29. Concrete shall be mixed in the proportions indicated in Table IV.

Variations in the grading of the aggregates, on which the proportions were based, may be made upon the approval of the Engineer and in such proportions as he may direct (Sections 3 and 14), but no claim shall be made for extra compensation therefor.

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[1] The Engineer must strike out one of these terms.

[2] The volume of fine aggregate is affected by the method of measurement and by the moisture content; corrections should be made, when necessary, to maintain the required proportions. See also footnote to Table IV.

The Engineer shall have the right to make any changes in proportions or materials that may be necessary or desirable, and proper adjustment of compensation will be made in accordance with the provisions of the contract.

In general the quantity of water used shall be the minimum necessary to produce concrete of a workability specified in Table V.

TABLE V.—WORKABILITY OF CONCRETE.

Type of Concrete.	Maximum Slump, in.
1. Mass concrete	[a]
2. Reinforced concrete:	
(a) Thin vertical sections and columns	[a]
(b) Heavy sections	[a]
(c) Thin confined horizontal sections	[a]
3. Roads and pavements:	
(a) Hand finished	[a]
(b) Machine finished	[a]
4. Mortar for floor finish	[a]

[a] The engineer must insert the maximum slumps permitted. The slump test requirement is intended to insure concrete mixed with the minimum quantity of water required to produce a plastic mixture. The following table indicates the maximum slump desirable for the various types of concrete, based on average aggregates and proportions:

Type of Concrete.	Maximum Slump, in.
1. Mass concrete	3
2. Reinforced concrete:	
(a) Thin vertical sections and columns	6
(b) Heavy sections	3
(c) Thin confined horizontal sections	8
3. Roads and pavements:	
(a) Hand finished	3
(b) Machine finished	1
4. Mortar for floor finish	2

Frequent tests[1] shall be made throughout the work, as directed by the Engineer, to determine whether the concrete produced by the proportions given in Table IV is of the quality specified. These tests shall be made in accordance with Section 4 and at the expense of the owner. The contractor shall provide such facilities as may be practicable for carrying out the tests, and shall cooperate in every way to the end that concrete of the desired quality shall be obtained.

B. *Consistency of Concrete.*

Consistency. 30. The quantity of water used shall be the minimum necessary to produce concrete of a workability required by the Engineer.[2] The consistency of the concrete shall be measured by the slump test as described in the Tentative Method of Test for Consistency of Portland-Cement Concrete for Pavements or for Pavement Base (Serial Designation: D 138 – 22 T) of the American Society for Testing Materials. (Appendix 11.) The slump for the different types of concrete shall not be greater than that indicated in Table V, unless authorized by the Engineer.

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[1] If no tests are to be made on concrete from available materials, or on the concrete mixed during the work, this paragraph shall be omitted.

[2] Attention is called to the fact that increased workability may be obtained by decreasing the quantity of coarse aggregate in the batch, without increasing the quantity of mixing water.

The consistency shall be checked from time to time during the progress of the work.

C. *Mixing.*

31. The mixing of concrete, unless otherwise authorized by the Engineer, shall be done in a batch mixer of approved type which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixer shall be equipped with suitable charging hopper, water storage, and a water-measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged before recharging. The mixer shall be cleaned at frequent intervals while in use. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer. **Machine Mixing.**

32. The mixing of each batch shall continue not less than one minute after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 ft. per minute. **Time of Mixing.**

33. When hand mixing is authorized by the Engineer it shall be done on a water-tight platform. The cement and fine aggregate shall first be mixed dry until the whole is of a uniform color. The water and coarse aggregate shall then be added and the entire mass turned at least three times, or until a homogeneous mixture of the required consistency is obtained. **Hand Mixing.**

34. The retempering of concrete or mortar which has partially hardened, that is, remixing with or without additional cement, aggregate, or water, will not be permitted. **Retempering.**

CHAPTER VI. DEPOSITING CONCRETE.

A. *Depositing in Air.*

35. Before beginning a run of concrete, hardened concrete and foreign materials shall be removed from the inner surfaces of the mixing and conveying equipment. **General.**

Approval. 36. Before depositing concrete, debris shall be removed from the space to be occupied by the concrete; forms shall be thoroughly wetted (except in freezing weather) or oiled. Reinforcement shall be thoroughly secured in position and approved by the Engineer.

Handling. 37. Concrete shall be handled from the mixer to the place of final deposit as rapidly as practicable by methods which shall prevent the separation or loss of the ingredients. It shall be deposited in the forms as nearly as practicable in its final position to avoid rehandling. It shall be so deposited as to maintain, until the completion of the unit, a plastic surface approximately horizontal. Forms for walls or other thin sections of considerable height, shall be provided with openings, or other devices, that will permit the concrete to be placed in a manner that will avoid accumulations of hardened concrete on the forms or metal reinforcement. Under no circumstances shall concrete that has partially hardened be deposited in the work.

Chuting. 38. When concrete is conveyed by chuting, the plant shall be of such size and design as to insure a practically continuous flow in the chute. The angle of the chute with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients.[1] The delivery end of the chute shall be as close as possible to the point of deposit. When the operation is intermittent, the spout shall discharge into a hopper. The chute shall be thoroughly flushed with water before and after each run; the water used for this purpose shall be discharged outside the forms.

Compacting. 39. Concrete, during and immediately after depositing, shall be thoroughly compacted by means of suitable tools. For thin walls or inaccessible portions of the forms, where rodding or forking is impracticable, the concrete shall be assisted into place by tapping or hammering the forms opposite the freshly deposited concrete. The concrete shall be thoroughly worked around the reinforcement, and around embedded fixtures, and into the corners of the forms.

Removal of Water. 40. Water shall be removed from excavations before concrete is deposited, unless otherwise directed by the Engineer. Any flow of water into the excavation shall be diverted through proper side drains to a sump, or be removed by other approved methods which will avoid washing the freshly deposited concrete. Water vent pipes and drains shall be filled by grouting or otherwise, after the concrete has thoroughly hardened.

Protection. 41. Exposed surfaces of concrete shall be protected from premature drying for a period of at least seven days after being deposited.

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[1] An angle of 27 deg., or one vertical to two horizontal, is the minimum slope which is considered permissible. Chuting through a vertical pipe is satisfactory when the lower end of the pipe is maintained as nearly as practicable to the surface of deposit, and the pipe full.

42. Concrete when deposited shall have a temperature of not less than 40° F. nor more than 120° F. In freezing weather suitable means shall be provided for maintaining the concrete at a temperature of at least 50° F. for not less than 72 hours after placing, or until the concrete has thoroughly hardened. The methods of heating the materials and protecting the concrete shall be approved by the Engineer. Salt, chemicals, or other foreign materials shall not be mixed with the concrete for the purpose of preventing freezing, unless approved by the Engineer. **Temperature of Concrete.**

43. Concrete shall be deposited continuously and as rapidly as practicable until the unit of operation, approved by the Engineer, is completed. Construction joints at points not provided for in the plans shall be made in accordance with the provisions in Section 69. **Depositing Continuously.**

44. Before depositing new concrete on or against concrete which has set, the forms shall be retightened, the surface of the set concrete shall be roughened as required by the Engineer, thoroughly cleaned of foreign matter and laitance, and saturated with water. The new concrete placed in contact with hardened or partially hardened concrete, shall contain an excess of mortar to insure bond. To insure this excess mortar at the juncture of the hardened and the newly deposited concrete, the cleaned and saturated surfaces of the hardened concrete, including vertical and inclined surfaces, shall first be slushed with a coating of neat cement grout against which the new concrete shall be placed before the grout has attained its initial set. **Bonding.**

B. *Rubble and Cyclopean Concrete.*

45. Rubble aggregate shall be thoroughly embedded in the concrete. The individual stones shall not be closer to any surface or adjacent stone than the maximum size of the coarse aggregate plus 1 in. Each successive layer of concrete shall be keyed in accordance with the provision in Section 69. **Rubble Concrete.**

46. Cyclopean aggregate shall be thoroughly embedded in the concrete; no stone shall be closer to a finished surface than 1 ft., nor closer than 6 in. to any adjacent stone. Stratified stone shall be laid on its natural bed. **Cyclopean Concrete.**

C. *Depositing Under Water.*[1]

47. The methods, equipment, and materials to be used shall be submitted to and approved by the Engineer before the work is started. **General.**

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[1] Concrete should not be deposited under water if practicable to deposit in air. There is always uncertainty as to the results obtained from placing concrete under water. Where conditions permit, the additional expense and delay of avoiding this method will be warranted. It is especially important that the aggregate be free from loam and other material which may cause laitance. Washed aggregates are preferable. Coarse aggregate consisting of washed gravel of a somewhat smaller size than that used in open-air concrete work will give best results. Concrete should never be deposited under water without experienced supervision. Many failures, especially of structures in sea water, can be traced directly to ignorance of proper methods or lack of expert supervision.

Concrete shall be deposited by a method that will prevent the washing of the cement from the mixture, minimize the formation of laitance and avoid flow of water until the concrete has fully hardened. Concrete shall be placed so as to minimize segregation of materials. Concrete shall not be placed in water having a temperature below 35° F.

Proportions. 48. Concrete to be deposited under water shall contain $1\frac{3}{4}$ bbl. (7 bags) or more of portland cement per cubic yard of concrete in place.

Cofferdams. 49. Cofferdams shall be sufficiently tight to prevent flow of water through the space in which the concrete is to be deposited. Pumping will not be permitted while concrete is being deposited, nor until it has fully hardened.

Depositing Continuously. 50. Concrete shall be deposited continuously, keeping the top surface as nearly level as possible, until it is brought above the water, or to the required height. The work shall be carried on with sufficient rapidity to prevent the formation of layers.

Method. 51. The following method[1] shall be used for depositing concrete under water:

(*a*) *Tremie.*—The tremie shall be water-tight and sufficiently large to permit a free flow of concrete. It shall be kept filled[2] at all times during depositing. The concrete shall be discharged and spread by raising the tremie in such manner as to maintain as nearly as practicable a uniform flow and avoid dropping the concrete through water. If the charge is lost during depositing the tremie shall be withdrawn and refilled.

(*b*) *Drop-Bottom Bucket.*—The bucket shall be of a type that cannot be dumped until it rests on the surface upon which the concrete is to be deposited. The bottom doors when tripped shall open freely downward and outward. The top of the bucket shall be open. The bucket shall be completely filled, and slowly lowered to avoid back-wash. When discharged, the bucket shall be withdrawn slowly until well above the concrete.

(*c*) *Bags.*—Bags of jute or other coarse cloth shall be filled about two-thirds full of concrete and carefully placed by hand in a header-and-stretcher system so that the whole mass is interlocked.

Laitance. 52. Great care shall be exercised to disturb the concrete as little as possible when it is being deposited in order to avoid the formation of laitance. On completing a section of concrete, the laitance shall be entirely removed before work is resumed.

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[1] The Engineer must strike out the method or methods not applicable to the work.

[2] The tremie may be filled by one of the following methods: (1) Place the lower end in a box partly filled with concrete, so as to seal the bottom, then lower into position; (2) plug the tremie with cloth sacks or other material, which will be forced down as the pipe is filled with concrete; (3) plug the end of the tremie with cloth sacks filled with concrete.

CHAPTER VII. FORMS.

53. Forms shall conform to the shape, lines and dimensions of the concrete as called for on the plans. Lumber used in forms for exposed surfaces shall be dressed to a uniform thickness, and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. For unexposed surfaces and rough work, undressed lumber may be used. Lumber once used in forms shall have nails withdrawn, and surfaces to be in contact with concrete thoroughly cleaned, before being used again. **General.**

54. Forms shall be substantial and sufficiently tight to prevent leakage of mortar; they shall be properly braced or tied together so as to maintain position and shape. If adequate foundation for shores cannot be secured, trussed supports shall be provided. **Design.**

55. Bolts and rods shall preferably be used for internal ties; they shall be so arranged that when the forms are removed no metal shall be within 1 in. of any surface. Wire ties will be permitted only on light and unimportant work; they shall not be used through surfaces where discoloration would be objectionable. Shores supporting successive stories shall be placed directly over those below, or so designed that the load will be transmitted directly to them. Forms shall be set to line and grade and so constructed and fastened as to produce true lines. Special care shall be used to prevent bulging. **Workmanship.**

56. Unless otherwise specified, suitable moldings or bevels shall be placed in the angles of forms to round or bevel the edges of the concrete. **Moldings.**

57. The inside of forms shall be coated with non-staining mineral oil or other approved material or thoroughly wetted (except in freezing weather). Where oil is used, it shall be applied before the reinforcement is placed. **Oiling.**

58. Temporary openings shall be provided at the base of column and wall forms, and at other points where necessary to facilitate cleaning and inspection immediately before depositing concrete. **Inspection.**

59. Forms shall not be disturbed until the concrete has adequately hardened.[1] Shoring shall not be removed until the member has acquired sufficient strength to safely support its weight and the load upon it. Members subject to additional loads during construction shall be adequately shored to support both the member and construction loads in such a manner as will protect the member from damage by the loads; this shoring shall not be removed until the member has acquired sufficient strength to safely support its weight and the load upon it. **Removal.**

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[1] Many conditions affect the hardening of concrete and the proper time for the removal of the forms should be determined by the Engineer.

CHAPTER VIII. DETAILS OF CONSTRUCTION.

A. Metal Reinforcement.

Cleaning. 60. Metal reinforcement, before being positioned, shall be thoroughly cleaned of mill and rust scale and of coatings that will destroy or reduce the bond. Reinforcement appreciably reduced in section shall be rejected. Where there is delay in depositing concrete, reinforcement shall be re-inspected and, when necessary, cleaned.

Bending. 61. Reinforcement shall be carefully formed to the dimensions indicated on the plans or as provided in Section 140. Cold bends shall be made around a pin having a diameter of four or more times the least dimension of the reinforcement bars for steel of structural grade and eight or more times that for steel of intermediate or hard grade.

Straightening. 62. Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks or bends not shown on the plans shall not be used. Heating of reinforcement will be permitted only when the entire operation is approved by the Engineer.

Placing. 63. Metal reinforcement shall be accurately positioned, and secured against displacement by using annealed iron wire of not less than No. 18 gage or suitable clips at intersections, and shall be supported by concrete or metal chairs or spacers, or metal hangers. The minimum clear distance between parallel bars shall be $1\frac{1}{2}$ times the diameter of round bars or $1\frac{1}{2}$ times the diagonal of square bars; if the ends of bars are anchored as specified in Section 140, the clear spacing may be made equal to the diameter of round bars or to the diagonal of square bars, but in no case shall the spacing between bars be less than 1 in., nor less than $1\frac{1}{4}$ times the maximum size of the coarse aggregate. Bars parallel to the face of any member shall be embedded a clear distance of not less than one diameter from the face.

Splicing. 64. In slabs, beams and girders, splices of reinforcement shall not be made at points of maximum stress without the approval of the Engineer. Splices, where permitted, shall provide sufficient lap to transfer the stress between bars by bond and shear. In such splices the bars shall be placed at the minimum distance specified in Section 63; adjacent bars shall not be spliced at the same point.

Splices in columns, piers and struts shall provide sufficient lap to transfer the stress by bond.

Offsets in Column Reinforcement. 65. Where changes in the cross-section of a compression member occur, the longitudinal reinforcement bars shall be sloped for the full length of the member or offset in a region where lateral support is afforded. Where offset, the slope of the inclined portion from the axis of the member shall not be more than 1 in 6.

Future Bonding. 66. Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion.

B. Protective Concrete Covering.

Moisture Protection. 67. Metal reinforcement in wall footings and column footings shall have a minimum covering of 3 in. of concrete. At surfaces of concrete exposed to the weather, metal reinforcement shall be protected by not less than 2 in. of concrete.

Fire Protection. 68. Metal reinforcement in fire-resistive construction shall be protected by not less than 1 in. of concrete in slabs and walls, and not less than 2 in. in beams, girders and columns, provided aggregate showing an expansion not materially greater than that of limestone or trap rock is used; when impracticable to obtain aggregate of this grade, the protective covering shall be 1 in. thicker and shall be reinforced with metal mesh having openings not exceeding 3 in., placed 1 in. from the finished surface.

In structures where the fire hazard is limited, the metal reinforcement shall not be placed nearer the exposed surface than $\frac{3}{4}$ in. in slabs and walls or $1\frac{1}{2}$ in. in beams, girders and columns.

C. Joints.

General. 69. Joints not indicated on the plans shall be so designed and located as to least impair the strength and appearance of the structure. To prevent laitance in horizontal joints, excess water shall be removed from the surface forming the joint after depositing the concrete. Surfaces of contact shall be cleaned and wetted before depositing is resumed, and any laitance shall be removed. Where additional resistance to horizontal shear is required, stones shall be partially embedded in such a manner as to key with the adjoining concrete; or mortices or keys shall be formed in the concrete.

Joints in Columns. 70. Joints in columns shall be made at the underside of the floor. Haunches and column capitals shall be considered as part of and to act continuous with the floor. At least two hours must elapse after depositing concrete in the columns or walls before depositing in beams, girders, or slabs.

Joints in Floors. 71. Construction joints in floors shall be located near the middle of spans of slabs, beams or girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. Adequate provision shall be made for shear by use of inclined reinforcement.

Construction Joints in Long Buildings.

72. Construction joints made crosswise of a building 100 ft. or more in length, shall have special reinforcement placed at right angles to the joint and extending a sufficient distance on each side of the joint to develop the strength of the reinforcement by bond. This reinforcement shall be placed near the opposite face of the member from the main tension reinforcement; the cross-sectional area of such reinforcement shall be not less than 0.5 per cent of the section of the members cut by the joint.

Expansion Joints.

73. Expansion joints shall be so detailed that the necessary movement may occur with the minimum resistance at the joint. The structure adjacent to the joint shall preferably be supported on separate columns or walls. Reinforcement shall not extend across an expansion joint; the break between the two sections shall be complete.[1] Exposed edges of expansion joints in walls or abutments shall be rounded. Exposed expansion joints between two distinct concrete members shall be filled with an elastic joint filler of approved quality.

Expansion Joints in Long Buildings.

74. Buildings exceeding 200 ft. in length and of width less than about one-half the length, shall be divided by means of expansion joints, located near the middle, but not more than 200 ft. apart, to minimize the destructive effects of temperature changes and shrinkage. Where there is an abrupt change in the width of a building, an expansion joint shall be provided.

Sliding Joints.

75. The seat of sliding joints shall be finished to a smooth plane surface and allowed to harden. Two thicknesses of building paper shall be placed on the seat before depositing superimposed concrete.[2]

Water-tight Construction Joints.

76. Where construction joints are required to be water-tight the method of construction shall be as follows:

(*a*) Horizontal joints shall be constructed by forming a continuous keyway in the lower portion of concrete before the concrete has hardened. Before placing the superimposed concrete the joint shall be thoroughly cleaned of laitance or other foreign material, saturated with water and coated with neat cement grout. The superimposed concrete shall be placed in such a manner as will insure an excess of mortar over the entire surface of the joint.

(*b*) Vertical joints shall be made by a metal water-stop approved by the Engineer.

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[1] A coating of white lead and oil, asphalt paint, petrolatum, or waterproofed building paper, placed over the entire surface of the hardened concrete, is commonly used for this purpose.

[2] Sheet zinc, lead, and bronze are also used for this purpose.

Seepage water shall be offered and drained from the forms, where required, vent pipes shall be closed after the concrete has thoroughly hardened.[1]

CHAPTER IX. WATERPROOFING AND PROTECTIVE TREATMENT

A. Waterproofing.

General. 77. Concrete required to be water-tight shall be made with strict adherence to all provisions in these specifications regarding the choice of materials, proportions, consistency, mixing, placing, protecting, and workmanship.

Integral Compounds. 78. Integral compounds shall not be used for waterproofing unless specifically authorized by the Engineer.

Water-tight Joints. 79. See Section 76.

B. Oilproofing.

Oilproofing. 80. Concrete containers for light mineral oils, animal oils, certain vegetable oils and other commercial liquids shall be given an inside coating which shall be applied before the container is placed in service; the coating and the method of application shall be approved by the Engineer.[2] Floors or other surfaces exposed to heavy concentrations of such oils or liquids shall be similarly protected.

C. Concrete in Sea Water.

Proportions. 81. Plain concrete in sea water from 2 ft. below low water to 2 ft. above high water, or from a plane below to a plane above wave action, shall contain a minimum of $1\frac{3}{4}$ bbl.(7 bags) of portland cement per cubic yard in place. Other plain concrete in sea water or exposed directly along the sea coast shall contain a minimum of $1\frac{1}{2}$ bbl. (6 bags) of portland cement per cubic yard in place. Porous or weak aggregates shall not be used.

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[1] To secure water-tight joints it is vitally essential that all incoming water be drained from behind the forms during the process of concreting. If the upper portion of the joint is concreted first, a metal water-stop should be provided as directed by the Engineer.

[2] The effect of certain oils and other liquids on concrete and surface treatments which have been found beneficial are given in Appendix 17.

Concrete containers for mineral oils of 30° Baumé and lighter should be given a coating which will not be affected or penetrated by mineral spirits. Coatings containing ingredients which saponify or oxidize in the presence of lime shall be applied only to a surface which has previously been treated to neutralize the lime.

Concrete containers for mineral oils heavier than 30° Baumé require no coating.

Certain vegetable and animal oils and strong acids and alkaline solutions have a destructive effect on concrete and some protective treatment is required. Several vegetable oils have a disintegrating effect on concrete in cases where the surface is alternately wet and dry, yet when stored in closed concrete containers have no injurious action.

Concrete containers for commercial liquids involve certain special features in addition to the general requirements of good concrete. Containers for such liquids often have thin sections, therefore a rich mixture is necessary to obtain concrete of proper workability without sacrificing strength and impermeability; it is especially necessary to eliminate joints or seams; thorough spading is essential and should be continuous during the placing of concrete.

Consistency. 82. The consistency shall meet the requirements of Section 30.

Depositing. 83. Sea water shall not be allowed to come in contact with the concrete until it has hardened for at least four days. Concrete shall be placed in such a manner as to minimize the number of horizontal or inclined seams or work planes. The placing of concrete between tides shall be a continuous operation, in accordance with the methods described in Section 43; where it is impossible to avoid seams or joints proceed as in Section 44. Concrete shall be deposited in sea water only when so directed by the Engineer, in which case it shall be placed in accordance with the methods described in Sections 47 to 52.

Protection. 84. Metal reinforcement shall be placed at least 3 in. from any plane or curved surface, except at corners when it shall be at least 4 in. from adjacent surfaces. Metal chairs, supports, or ties shall not extend to the surface of the concrete. Where unusually severe conditions of abrasion are anticipated, the face of the concrete from 2 ft. below low water to 2 ft. above high water, or from a plane below to a plane above wave action, shall be protected by creosoted timber, dense vitrified shale brick, or stone of suitable quality, as designated on the plans or as required by the Engineer.

D. *Concrete in Alkali Soils or Waters.*[1]

Proportions. 85. Concrete in alkali waters or below ground-line of alkali soils shall contain a minimum of $1\frac{3}{4}$ bbl. (7 bags) of portland cement per cubic yard in place.[2]

Consistency. 86. The consistency of concrete in alkali soils or waters shall be such as to meet the requirements of Section 30.

Placing. 87. Concrete shall be placed in such a manner as to minimize the number of horizontal or inclined seams, or work planes.

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[1] Under certain circumstances concrete is attacked by alkaline waters. The term "alkali" is here used to designate the soluble salts which occur in considerable quantities in the soils and waters of certain Western States; the sulfates, chlorides, and carbonates of sodium and magnesium are the most common forms of alkali.

It is important to distinguish between the different forms of alkali which occur in nature. Experience and tests have shown that certain forms are more injurious than others; the chlorides and carbonates produce little or no injury to concrete.

Special care must be used in placing concrete where it will be exposed to sulfate waters. An impermeable concrete made with a durable aggregate is necessary. Concrete should be permitted so harden under favorable conditions before it is exposed to injurious alkalies, and wherever practicable such concrete should be made in the form of precast units.

[2] Where the foundations of important buildings or similar structures are subject to high concentrations of alkalies, under-drainage may be used as an added precaution.

88. Metal reinforcement or other corrodible metal shall not be placed closer than 2 in. to the surface of members exposed to alkali soils or waters. In foundations and in heavy structures the metal reinforcement shall not be placed closer than 3 in. to the surface. **Protection.**

CHAPTER X. SURFACE FINISH[1]

89. The requirements in these specifications applying to forms, and to mixing, conveying, depositing and finishing concrete, shall be followed unless modified by the plans. **General.**

The whole of a showing face between prescribed construction joints shall be cast in one continuous operation. Construction joints, when not shown on the plans, shall be made as directed by the Engineer, and shall be true to line with sharp unbroken edges.

The same brand of cement, and the same kind and size of aggregate, shall be used throughout the whole of any showing face.

For showing faces the forms shall be smooth and water-tight. If wood be used, the boards shall be planed, grooved and tongued, evenly matched and tightly placed. They shall be so constructed as to be removable in sections by unscrewing or otherwise loosening them without hammering or prying against the face. Any offsets in the forms that may occur shall be smoothly dressed and any openings pointed flush with stiff clay or plaster of Paris in order to prevent leakage or the formation of fins.

Concrete that is to have a showing face, whether any particular finish is called for or not, shall be mixed, placed and worked as may be necessary to secure at the face a uniform distribution of the aggregates, freedom from void spaces, and uniform texture. If the finish is required to be one that will expose the coarse aggregate, by either scrubbing, tooling, sand-blasting, or acid treatment, then after the full surface of mortar has been worked against the form, the spading tool shall be inserted in the concrete and the coarse aggregate be pressed against the form in order to secure uniform distribution at the face and a uniform texture after the aggregate is exposed.

Face forms shall be removed as soon as practicable in order to facilitate effective repair of void spaces or broken corners, before the surface has dried. Care shall be taken to avoid roughening or injuring corners, and to keep edges sharp.

As soon as the face forms are removed any fins or other projections shall be carefully removed, and offsets leveled, and any voids or damaged places shall immediately be saturated with water and filled with a mixture of the same composition as that used in the surface, and brought even with the surface by means of a wooden spatula or float. A steel trowel shall not be used to finish the surface. The face shall be finished free from streaks, discolorations or other imperfections. Plastering will not be permitted.

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[1] The Engineer must indicate on the plans the type of finish desired and must strike out the sections which do not apply.

Where a surface of mortar is to be the basis of the finish the coarse aggregate shall be worked back from the form with a suitable tool, so as to bring a full surface of mortar against the form, care being taken to prevent the formation of voids and air pockets.

Whenever forms are removed from showing faces before the concrete has become hard and dry, the surface of the concrete shall be immediately wetted and kept wet for at least three days.

Granolithic Surfaces.

90. Granolithic surfaces shall be made by placing about 1 in. of facing concrete against the face form in advance of the concrete, of such consistency and in such a manner as will insure its bonding with the concrete.

The facing concrete shall be composed of 1 part portland cement, 1½ parts fine aggregate, and 2½ parts coarse aggregate made up of pebbles, crushed granite, or other stone as called for.

If iron or wooden molds are used to retain the facing against the forms while placing concrete, care should be taken that the mold is not permitted to remain until initial setting occurs. The molds shall be jarred frequently and raised at short intervals to prevent formation of seams and air spaces between the surface and the concrete.

Top Surfaces not Subject to Wear.

91. Top surfaces not subject to wear shall be smoothed with a wood float and be kept wet for at least seven days. Care shall be taken to avoid an excess of water in the concrete, and to drain or otherwise promptly remove any water that comes to the surface. Dry cement, or a dry mixture of cement and sand, shall not be sprinkled directly on the surface.

A. Wearing Surfaces.

One-Course Work.

92. Aggregates for the wearing surface shall have a high resistance to abrasion, and shall be screened and when necessary thoroughly washed. The least quantity of mixing water that will produce a dense concrete shall be used. The mix shall not be leaner than 1 part of Portland cement and 2½ parts of aggregate. The surface shall be screeded even and finished with a wood float. Excess water shall be promptly drained or otherwise removed. Overtroweling shall be avoided.

Two-Course Work. 93. The wearing surface in two-course work shall be placed within $\frac{1}{2}$ hour after the base course. Where the wearing surface is required to be applied to a hardened base course, the latter shall be prepared by roughening with a pick or other effective tool. The roughened surface shall be thoroughly saturated with water and covered with a thin layer of neat cement paste immediately before the wearing surface is placed. The wearing course shall not be thinner than 1 in.

Curing. 94. Concrete wearing surfaces made in accordance with Sections 92 and 93, shall be kept wet[1] for at least 10 days in the case of floors and 21 days in the case of roads and pavements.

Terrazzo Finish. 95.[2] Terrazzo finish shall be made by mixing 1 part of cement, $2\frac{1}{2}$ parts of crushed marble, or other stone or crushed pebbles, as may be called for by the plans, and sufficient water to produce a dense concrete. The concrete shall be spread on the base course and worked down to a thickness of 1 in. by patting or rolling and troweling. The marble shall all pass a $\frac{1}{2}$-in. screen and be free from dust. The surface shall be kept wet for not less than ten days, and after curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Section 93.

Terrazzo Finish. 95.[2] Terrazzo finish shall be made by mixing 1 part of cement, 2 parts of sand and sufficient water to produce a plastic mortar, which shall be spread on the base course to a depth of 1 in. Crushed marble, free from dust and passing a $\frac{1}{4}$-in. screen, shall be sprinkled over the surface of the fresh mortar and pressed or rolled in. The surface shall be kept wet for not less than ten days and after curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Section 93.

B. Decorative Finishes:

Rubbed Finish. 96. Immediately after the forms are removed, the surface shall be wetted and rubbed with a carborundum brick or other abrasive until even and smooth and of uniform appearance, without applying any cement or other coating.

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[1] Prevention of premature drying during the early hardening of concrete is essential to the development of high resistance to abrasion. The surface may be covered with a layer of burlap, earth or sand, kept wet, or it may be divided into small areas by dikes and flooded with water to a depth of 2 or 3 in.

[2] The Engineer must strike out one of the Sections 95.

Scrubbed Finish. 97. The forms shall be removed and the scrubbing done before the concrete has hardened.[1] The surface shall be scrubbed with fiber or wire brushes using water freely, until the surface film of mortar is removed and the aggregate uniformly exposed; then rinsed with clean water. If portions of the surface have become too hard to scrub in equal relief, dilute hydrochloric acid (1 part acid to 4 parts water) may be used to facilitate the scrubbing. The remaining acid shall be thoroughly removed with clean water.

Sand-Blast Finish. 98. The concrete face shall be permitted to attain an intermediate degree of hardness; it shall then be air-blasted with hard sand until the aggregate is in uniform relief.

Tooled Finish. 99. The surface shall be permitted to become dry and hard, and then dressed with tools, as called for,[2] to a uniform texture and even face.

Sand Floated Finish. 100. The forms shall be removed before the surface has fully hardened; the surface shall be rubbed with a wooden float by a uniform circular motion, fine sand being rubbed into the surface until the resulting finish is even and uniform.

Colored Aggregate Finish. 101. Colored or other special aggregate used for finish shall be exposed by scrubbing as provided in Section 97. Facing mortar, made from this special aggregate, of 1 part of cement, $1\frac{1}{2}$ parts of sand, and 3 parts of pebbles or screenings, clean and free from dust, shall be placed against the face forms to a thickness of about 1 in., sufficiently in advance of the concrete to prevent the latter coming in contact with the form.

Colored Pigment Finish. 102. Mineral pigment shall be thoroughly mixed dry with the cement and fine aggregate; care shall be taken to secure a uniform tint throughout.

CHAPTER XI. DESIGN.

A. General Assumptions.

General Assumptions. 103. The design of reinforced concrete members under these specifications shall be based on the following assumptions:

(*a*) Calculations are made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

(*b*) A plane section before bending remains plane after bending, shearing distortions being neglected.

(*c*) The modulus of elasticity of concrete in compression is constant within the limits of working stresses and the distribution of compressive stress in beams is rectilinear.

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[1] In warm weather this will require from 6 to 24 hours, and in cold weather from 1 to 3 days.

[2] By axing, rough or fine pointing, or bush-hammering.

(*d*) The moduli of elasticity of concrete in computations for the position of the neutral axis, for the resisting moment of beams, and for compression of concrete in columns, are as follows:

(1) $\frac{1}{15}$ that of steel, when the compressive strength of the concrete at 28 days exceeds 1500 and does not exceed 2200 lb. per sq. in.;

(2) $\frac{1}{12}$ that of steel, when the compressive strength of the concrete at 28 days exceeds 2200 and does not exceed 2900 lb. per sq. in.;

(3) $\frac{1}{10}$ that of steel, when the compressive strength of the concrete at 28 days is greater than 2900 lb. per sq. in.

(*e*) In calculating the moment of resistance of reinforced concrete beams and slabs the tensile resistance of the concrete is neglected.

(*f*) The bond between the concrete and the metal reinforcement remains unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion of their moduli of elasticity.

(*g*) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.[1]

B. *Flexure of Rectangular Reinforced Concrete Beams and Slabs.*

104. Computations of flexure in rectangular reinforced concrete beams and slabs shall be based on the following formulas: **Flexure Formulas.**

(*a*) *Reinforced for Tension Only.*

Position of neutral axis,

$$k=\sqrt{2pn+(pn)^2}-pn \quad \ldots\ldots\ldots\ldots (1)$$

Arm[2] of resisting couple,

$$j=1-\frac{k}{3} \quad \ldots\ldots\ldots\ldots (2)$$

Compressive unit stress[2] in extreme fiber of concrete,

$$f_c=\frac{2M}{jkbd^2}=\frac{2pf_s}{k} \quad \ldots\ldots\ldots\ldots (3)$$

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[1] Formula 43 for the permissible compressive stress in reinforced concrete columns takes into account the effect of shrinkage in the concrete on the stress in the longitudinal reinforcement. It is not required, however, that the designer consider shrinkage stresses in columns, except through the use of that formula.

[2] For $f_s = 16{,}000$ to 18,000 lb. per sq. in. and $f_c = 800$ to 900 lb. per sq. in., j may be assumed as 0.86. For values of pn varying from 0.04 to 0.24, jk is approximately equal to $0.67\sqrt[3]{pn}$.

Tensile unit stress[1] in longitudinal reinforcement,

$$f_s=\frac{M}{A_sjd}=\frac{M}{pjbd^2} \tag{4}$$

Steel ratio for balanced reinforcement,

$$p=\tfrac{1}{2}\,\frac{1}{\dfrac{f_s}{f_c}\left(\dfrac{f_s}{nf_c}+1\right)} \tag{5}$$

For formulas on shear and bond, see Sections 121–127 and 135–137.

(*b*) *Reinforced for Both Tension and Compression.*

Position of neutral axis,

$$k=\sqrt{2n\left(p+p'\frac{d'}{d}\right)+n^2(p+p')^2}-n(p+p') \tag{6}$$

Position of resultant compression,

$$z=\frac{\tfrac{1}{3}k^3d+2p'nd'\left(k-\dfrac{d'}{d}\right)}{k^2+2p'n\left(k-\dfrac{d'}{d}\right)} \tag{7}$$

Arm[1] of resisting couple,

$$jd=d-z \tag{8}$$

Compressive unit stress in extreme fiber of concrete,

$$f_c=\frac{6M}{bd^2\left[3k-k^2+\dfrac{6p'n}{k}\left(k-\dfrac{d'}{d}\right)\left(1-\dfrac{d'}{d}\right)\right]} \tag{9}$$

Tensile unit stress in longitudinal reinforcement,

$$f_s=\frac{M}{pjbd^2}=nf_c\frac{1-k}{k} \tag{10}$$

Compressive unit stress in longitudinal reinforcement,

$$f'_s=nf_c\,\frac{k-\dfrac{d'}{d}}{k} \tag{11}$$

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[1] For f_s=16,000 to 18,000 lb. per sq. in. and f_c=800 to 900 lb. per sq. in., j may be assumed as 0.86. For values of pn varying from 0.04 to 0.24, jk is approximately equal to $0.67\sqrt[3]{pn}$.

105. The symbols[1] used in Formulas 1 to 23 are defined as follows: **Notation.**

A_s = effective cross-sectional area of metal reinforcement in tension in beams;

b = width of rectangular beam or width of flange of T–beam;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

f_c = compressive unit stress in extreme fiber of concrete;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from center to center of supports—see Section 106);

M = bending moment or moment of resistance in general;

n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams = A_s/bd;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

w = uniformly distributed load per unit of length of beam or slab;

z = depth from compression surface of beam or slab of resultant of compressive stresses.

106. The span length, l, of freely supported beams and slabs, shall be the distance between centers of the supports, but shall not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams built to act integrally with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam and making an angle of 45 deg. or more with the horizontal axis of a restrained beam are built to act integrally with the beam and support, the span shall be measured from the section where the combined depth of the beam and bracket is at least one-third more than the depth of the beam, but no portion of such a bracket shall be considered as adding **Span Length.**

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[1] For illustration of notation as applied to typical beams or slabs, see Figs. 1 and 2.

to the effective depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span, as defined above.

Slightly Restrained Beams of Equal Span.

107. Beams and slabs of equal spans built to act integrally with beams, girders, or other slightly restraining supports and carrying uniformly distributed loads shall be designed for the following moments at critical sections:

(*a*) Beams and slabs of one span,
Maximum positive moment near center,

$$M=\frac{wl^2}{8}\dots\dots\dots(12)$$

(*b*) Beams and slabs continuous for two spans only,
(1) Maximum positive moment near center,

$$M=\frac{wl^2}{10}\dots\dots\dots(13)$$

(2) Negative moment over interior support,

$$M=\frac{wl^2}{8}\dots\dots\dots(14)$$

(*c*) Beams and slabs continuous for more than two spans,
(1) Maximum positive moment near center and negative moment at support of interior spans,

$$M=\frac{wl^2}{12}\dots\dots\dots(15)$$

(2) Maximum positive moment near centers of end spans and negative moment at first interior support,

$$M=\frac{wl^2}{10}\dots\dots\dots(16)$$

(*d*) Negative moment at end supports for cases (*a*), (*b*), (*c*) of this section,

$$M=\text{not less than }\frac{wl^2}{16}\dots\dots\dots(16a)$$

Beams Built Into Brick or Masonry Walls.

108. Beams and slabs built into brick or masonry walls in a manner which develops partial end restraint shall be designed for a negative moment at the support of

$$M=\text{not less than }\frac{wl^2}{16}\dots\dots\dots(17)$$

Freely Supported Beams of Equal Span

109. Beams and slabs of equal spans freely supported and assumed to carry uniformly distributed loads shall be designed for the moments specified in Section 107, except that no reinforcement for negative moment need be provided at end supports where effective measures are taken to prevent end restraint. The span shall be taken as defined in Section 106 for freely supported beams.

Restrained Beams of Equal Span.

110. Beams and slabs of equal span built to act integrally with columns, walls, or other restraining supports and assumed to carry uniformly distributed loads, shall (except as provided in Section 107) be designed for the following moments at critical sections:

(*a*) Interior spans,

(1) Negative moment at interior supports except the first,

$$M = \frac{wl^2}{12} \dots\dots\dots\dots (18)$$

(2) Maximum positive moment near centers of interior spans,

$$M = \frac{wl^2}{16} \dots\dots\dots\dots (19)$$

(*b*) End spans of continuous beams and beams of one span in which I/l is less than twice the sum of the values of I/h for the exterior columns above and below which are built into the beams:

(1) Maximum positive moment near center of span and negative moment at first interior supports,

$$M = \frac{wl^2}{12} \dots\dots\dots\dots (20)$$

(2) Negative moment at exterior supports,

$$M = \frac{wl^2}{12} \dots\dots\dots\dots (21)$$

(*c*) End spans of continuous beams, and beams of one span, in which I/l is equal to or greater than twice the sum of the values of I/h for the exterior column above and below which are built into the beams:

(1) Maximum positive moment near center of span and negative moment at first interior support,

$$M = \frac{wl^2}{10} \dots\dots\dots\dots (22)$$

(2) Negative moment at exterior support,

$$M = \frac{wl^2}{16} \qquad (23)$$

Continuous Beams of Unequal Spans or with Non-uniform Loading.

111. Continuous beams with unequal spans, or with other than uniformly distributed loading, whether freely-supported or restrained, shall be designed for the actual moments under the conditions of loading and restraint.

Provision shall be made where necessary for negative moment near the center of short spans which are adjacent to long spans, and for the negative moment at the end supports, if restrained.

Unsupported Flange Length.

112. The distance between lateral supports of the compression area of a beam shall not exceed 24 times the least width of compression flange.

C. *Flexure of Reinforced Concrete T-Beams.*

Flexure Formulas.

113. Computations of flexure in reinforced concrete T-beams shall be based on the following formulas:

(*a*) *Neutral Axis in the Flange.*

Use formulas for rectangular beams and slabs in Section 104.

(*b*) *Neutral Axis below the Flange.*

Position of neutral axis,

$$kd = \frac{2ndA_s + bt^2}{2nA_s + 2bt} \qquad (24)$$

Position of resultant compression,

$$z = \left(\frac{3kd - 2t}{2kd - t}\right)\frac{t}{3} \qquad (25)$$

Arm of resisting couple,

$$jd = d - z \qquad (26)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n}\left(\frac{k}{1-k}\right) \qquad (27)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \qquad (28)$$

Formulas 24, 25, 26, 27 and 28 neglect compression in the stem.[1]

Notation. 114. The symbols[2] used in Formulas 24 to 28 are defined in Section 105, except as follows:

b' = width of stem of T-beam;
t = thickness of flange of T-beam.

Flange Width. 115. Effective and adequate bond and shear resistance shall be provided in beam-and-slab construction at the junction of the beam and slab; the slab shall be built and considered an integral part of the beam; the effective flange width to be used in the design of symmetrical T-beams shall not exceed one-fourth of the span length of the beam, and its overhanging width on either side of the web shall not exceed eight times the thickness of the slab nor one-half the clear distance to the next beam.

For beams having a flange on one side only, the effective flange width to be used in design shall not exceed one-tenth of the span length of the beam, and its overhanging width from the face of the web shall not exceed six times the thickness of the slab nor one-half the clear distance to the next beam.

Transverse Reinforcement. 116. Where the principal slab reinforcement is parallel to the beam, transverse reinforcement, not less in amount than 0.3 per cent of the sectional area of the slab, shall be provided in the top of the slab and shall extend across the beam and into the slab not less than two-thirds of the width of the effective flange overhang. The spacing of the bars shall not exceed 18 in.

Compressive Stress at Supports. 117. Provision shall be made for the compressive stress at the support in continuous T-beam construction.

Shear. 118. The flange of the beam shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

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[1] The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem:

Position of neutral axis,

$$kd=\sqrt{\frac{2ndA_s+(b-b')t^2}{b'}+\left(\frac{nA_s+(b-b')t}{b'}\right)^2}-\frac{nA_s+(b-b')t}{b'}\qquad(24a)$$

Position of resultant compression,

$$z=\frac{(kdt^2-\frac{2}{3}t^3)b+[(kd-t)^2(t+\frac{1}{3}(kd-t))]\,b'}{t(2kd-t)b+(kd-t)^2b'}\qquad(25a)$$

Arm of resisting couple (see footnote Section 106),

$$jd=d-z\qquad(26a)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c=\frac{2Mkd}{[(2kd-t)bt+(kd-t)^2b']\,jd}\qquad(27a)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s=\frac{M}{A_sjd}\qquad(28a)$$

[2] For illustration of certain symbols as applied to typical T-beams, see Fig. 3, Appendix 1.

Isolated Beams. 119. Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the width of the web and a total flange width not more than 4 times the web thickness.

D. Diagonal Tension and Shear.

Notation. 120. The symbols used in Formulas 29 to 35 are defined in Section 105, except as follows:

A_v = total area of web reinforcement in tension within a distance s, that is $s_1, s_2, s_3, \dots s_n$, or the total area of all bars bent up in any one plane;

α = angle between web bars and longitudinal bars;

F = total tension in a bar;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 13) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 12);

f_v = tensile unit stress in web reinforcement;

Q = ratio of the average to the maximum bond stress computed by Formula 34 within the distance y;

Σo = sum of perimeters of bars in one set;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

s = spacing of web bars or stirrups measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel (see Appendix 1, Fig. 14);

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel (see Appendix 1, Fig. 14);

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

x = length of bar added for anchorage, including the hook, if any;

y = distance from the point at which tension is computed to the point of beginning of anchorage.

Formula for Shear.

121. The shearing unit-stress, v, in reinforced concrete beams shall be taken as not less than that computed by Formula 29.[1]

$$v = \frac{V}{bjd} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

Variation of Shear in Beams with Uniform Load.

122. For purpose of design of beams carrying uniform loads, not less than one-fourth of the total shearing resistance required at either end of span shall be provided at the section where the computed shearing stress is zero; from that section to the ends of span the required shearing resistance shall be assumed to vary uniformly.

Width of Beams in Shear Computations.

123. The shearing unit stress shall be computed on the minimum width of rectangular beams and on the minimum thickness of the web in beams of I or T-section.

Shear in Beam-and-Tile Construction.

124. The width of the effective section for shear as governing diagonal tension shall be assumed as the thickness of the concrete web plus one-half the thickness of the vertical webs of the concrete or clay tile in contact with the beam. (For typical design see Appendix 1, Fig. 13.)

Types and Spacing of Web Reinforcement.

125. Web reinforcement may consist of:

(*a*) Vertical stirrups or web reinforcing bars;

(*b*) Inclined stirrups or web reinforcing bars forming an angle of 30 deg. or more with the longitudinal bars;

(*c*) Longitudinal bars bent up at an angle of 15 deg. or more with the direction of the longitudinal bars.

Stirrups or bent-up bars which are not anchored at both ends, according to the provisions of Section 141, shall not be considered effective as web reinforcement. When the shearing stress is not greater than $0.06 f'_c$, the distance s measured in the direction of the axis of the beam between two successive stirrups, or between two successive points of bending up of bars, or from the point of bending up of a bar to the edge of the support, shall not be greater than

$$s = \frac{45d}{\alpha + 10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

where the angle α is in degrees.

When the shearing stress is greater than $0.06 f'_c$, the distance s shall not be greater than two-thirds of the values given by Formula 30.

Anchorage of Web Reinforcement.

126. See Section 141.

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[1] For I or T-beams b is the width of the stem as given in Section 123.

Beams Without Special Anchorage of Longitudinal Reinforcement.

127. The shearing unit stress computed by Formula 29 in beams in which the longitudinal reinforcement is without special anchorage shall not exceed the values given by Formulas 31 and 32 and in no case shall it exceed $0.06f'_c$.

When α is between 45 and 90 deg.,

$$v = 0.02f'_c + \frac{f_v A_v}{bs \sin \alpha} \dots\dots\dots\dots (31)$$

When α is less than 45 deg.,

$$v = 0.02f'_c + \frac{f_v A_v}{bs} (\sin \alpha + \cos \alpha) \dots\dots\dots\dots (32)$$

Beams With Special Anchorage of Longitudinal Reinforcement.

128. The shearing unit stress computed by Formula 29 in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in Section 140, shall not exceed the value given by Formulas 31 and 32, when $0.03f'_c$ is substituted for $0.02f'_c$ in those formulas; in no case shall the shearing unit stress exceed $0.12f'_c$.

Beams with Bars Bent up at a Single Point.

129. Where the web reinforcement consists of bars bent up at a single point, the point of bending shall be at a distance s from the edge of the support, not greater than that given in Section 125 and the value of the quantity $\frac{f_v A_v}{bs} (\sin \alpha + \cos \alpha)$ used in the design shall not exceed 75 lb. per sq. in. (See Appendix 1, Fig. 10.)

Combined Web Reinforcement.

130. Where two or more types of web reinforcement are used in conjunction, the total shearing resistance of the beam shall be assumed as the sum of the shearing resistances computed for the various types separately. In such computations the shearing resistance of the concrete (the term $0.02f'_c$ or $0.03f'_c$ in Formulas 31 and 32) shall be included only once. In no case shall the maximum shearing stresses be greater than the limiting values given in Sections 127 and 128.

Shearing Stress in Flat Slabs.

131. The shearing unit stress in flat slabs shall not exceed the value of v as given by Formula 33,

$$v = 0.02\, f'_c (1 + r) \dots\dots\dots\dots (33)$$

and shall not in any case exceed $0.03f'_c$.

The shearing unit stress shall be computed on:

(*a*) A vertical section which has a depth in inches of $\frac{7}{8}(t_1 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_1 - 1\frac{1}{2}$ from the edge of the column capital; and

(*b*) A vertical section which has a depth in inches of $\frac{7}{8}(t_2 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_2 - 1\frac{1}{2}$ from the edge of the dropped panel.

In no case shall r be less than 0.25. Where the shearing stress computed as in (*a*) is being considered, r shall be assumed as the proportional amount of the negative reinforcement, within the column strip, crossing the column capital. Where the shearing stress computed as in (*b*) is being considered, r shall be assumed as the proportional amount of the negative reinforcement, within the column strip, crossing entirely over the dropped panel.[1] (For typical flat slab and designation of principal design sections see Appendix 1, Figs. 14 and 15.)

Shear and Diagonal Tension in Footings.

132. The shearing stress shall be taken as not less than that computed by Formula 29. The stress on the critical section, shall not exceed $0.02f'_c$ for footings with straight reinforcement bars, nor $0.03f'_c$ for footings in which the reinforcement bars are anchored at both ends by adequate hooks or otherwise as specified in Section 140.

Critical Section for Soil Footings.

133. The critical section for diagonal tension in footings on soil shall be computed on a vertical section through the perimeter of the lower base of a frustum of a cone or pyramid which has a base angle of 45 deg., and which has for its top the base of the column or pedestal and for its lower base the plane at the centroid of longitudinal reinforcement.

Critical Section for Pile Footings.

134. The critical section for diagonal tension in footings on piles shall be computed on a vertical section at the inner edge of the first row of piles entirely outside a section midway between the face of the column or pedestal and the section described in Section 133 for soil footings, but in no case outside of the section described in Section 133. The critical section for piles not arranged in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum described in Section 133.

E. Bond and Anchorage.

Bond Stresses by Beam Action.

135. Where bar reinforcement is used to resist tensile stresses developed by beam action, the bond stress shall be taken as not less than that computed by Formula 34,

$$u = \frac{V}{\Sigma ojd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (34)$$

For continuous or restrained members, the critical section for bond for the positive reinforcement shall be assumed to be at the point of inflection; that for the negative reinforcement shall be assumed to be at the face of the support, and at the point of inflection. For simple beams or freely supported end spans of continuous beams, the critical section for bond shall be assumed to be at the face of the support.

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[1] In special cases, where supported by satisfactory engineering analysis, diagonal tension reinforcement may be used and increased shearing stresses allowed in accordance with Sections 127 to 130.

Bent-up longitudinal bars which, at the critical section, are within a distance $\frac{d}{3}$ from horizontal reinforcement under consideration, may be included with the straight bars in computing Σo.

In footings only the bars specified in Section 177 as effective in resisting bending moment shall be considered as resisting bond stresses. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surface, as maximum bond stresses may occur at the vertical plane of the steps or near the edges of the footing.

Bond Stress for Ordinary Anchorage.

136. In beams where the ordinary anchorage described in Section 139 is provided, the bond stress computed by Formula 34 at any section shall not exceed the following values:

For plain bars.................................... $u = 0.04f'_c$
For deformed bars meeting the requirements of Section 23.................................... $u = 0.05f'_c$

Bond Stresses for Special Anchorage.

137. In beams where special anchorage of the bars is provided as specified in Section 140, bond stresses exceeding those specified in Section 136 may be used, provided the total tensile stress at a point of abrupt change in stress or at the point of maximum stress, does not exceed the value of F given by Formula 35,

$$F = Qu\Sigma oy + u\Sigma ox \qquad (35)$$

where F = total tension in the bar;
Σo = the perimeter of the bar under consideration;
Q = ratio of the average to the maximum bond stress computed by Formula 34 within the distance y.
u = permissible bond stress = $0.04f'_c$ for plain and $0.05f'_c$ for deformed bars meeting the requirements of Section 23;
x = the length of bar added for anchorage, including the hook, if any;
y = distance from the point at which the tension is computed to the point of beginning of anchorage.

The length of bar added for anchorage may be either straight or bent. The radius of bend shall not be less than four bar diameters.

Bond Stress for Reinforcement in Two or More Directions.

138. The permissible bond stress for footings and similar members in which reinforcement is placed in more than one direction shall not exceed 75 per cent of the values in Sections 136 and 137.

Ordinary Anchorage Requirements.

139. In continuous, restrained or cantilever beams, anchorage of the tensile negative reinforcement beyond the face of the support shall provide for the full maximum tension with bond stresses not greater than those specified in Section 136. Such anchorage shall provide a length of bar not less than the depth of the beam. In the case of end supports which have a width less than three-fourths of the depth of the beam, the bars shall be bent down toward the support a distance not less than the effective depth of the beam. The portion of the bar so bent down shall be as near to the end of the beam as protective covering permits. (See Fig. 9.) In continuous or restrained beams, negative reinforcement shall be carried to or beyond the point of inflection. Not less than one-fourth of the area of the positive reinforcement shall extend into the support to provide an embedment of ten or more bar diameters.

In simple beams or freely supported end spans of continuous beams at least one-fourth of the area of the tensile reinforcement shall extend along the tension side of the beam and beyond the face of the support to provide an embedment of ten or more bar diameters.

Special Anchorage Requirements.

140. Where increased shearing stresses are used as provided in Sections 128 and 132 or increased bond stresses as provided in Section 137, special anchorage of all reinforcement in addition to that required in Section 139 shall be provided as follows:

(*a*) In continuous and restrained beams, anchorage beyond points of inflection of one-third the area of the negative reinforcement and beyond the face of the support of one-third the area of the positive reinforcement, shall be provided to develop one-third of the maximum working stress in tension, with bond stresses not greater than those specified in Section 136.

(*b*) At the edges of footings, anchorage for all the bars for one-third the maximum working stress in tension shall be provided within a region where the tension in the concrete, computed as an unreinforced beam, does not exceed 40 lb. per sq. in.

(*c*) In simple beams or freely supported end spans of continuous beams, at least one-half of the tensile reinforcement shall extend along the tension side of the beam to provide an anchorage beyond the face of the support for one-third of the maximum working stress in tension.

Anchorage of Web Reinforcement.

141. Web bars shall be anchored at both ends by:

(*a*) providing continuity with the longitudinal reinforcement; or

(*b*) bending around the longitudinal bar; or (*c*) a semi-circular hook which has a radius not less than four times the diameter of the web bar.

Stirrup anchorage shall be so provided in the compression and tension regions of a beam as to permit the development of safe working tensile stress in the stirrup at a point $0.3d$ from either face.[1]

The end anchorage of a web member not in bearing on the longitudinal reinforcement shall be such as to engage an amount of concrete sufficient to prevent the bar from pulling out. In all cases the stirrups shall be carried as close to the upper and lower surfaces as fireproofing requirements permit. (For typical designs see Appendix 1, Figs. 8 and 12.)

F. Flat Slabs.

(Two-Way and Four-Way Systems with Rectangular Panels.)

Moments in Interior Panels.

142. The moment coefficients, moment distribution and slab thicknesses specified herein are for slabs which have three or more rows of panels in each direction, and in which the panels are approximately uniform in size. Slabs with paneled ceiling or with depressed paneling in the floor shall be considered as coming under the requirements herein given. The symbols used in Formulas 36 to 41 are defined in Section 105 except as indicated in Sections 142, 145 and 155.

In flat slabs in which the ratio of reinforcement for negative moment in the column strip is not greater than 0.01, the numerical sum of the positive and negative moments in the direction of either side of the panel for which tension reinforcement must be provided, shall be assumed as not less than that given by Formula 36,

$$M_0 = 0.09\ Wl\left(1 - \frac{2c}{3l}\right)^2 \quad \text{.................} (36)$$

where M_0 = sum of positive and negative bending moments[2] in either rectangular direction at the principal design sections of a panel of a flat slab;

c = base diameter of the largest right circular cone, which lies entirely within the column (including the capital) whose vertex angle is 90 deg. and whose base is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (see Fig. 14);

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[1] Generally a properly-anchored stirrup whose diameter does not exceed $\frac{1}{50}$ of the depth of the beam will meet these requirements.

[2] The sum of the positive and negative moments provided for by this equation is about 72 per cent of the moment found by rigid analysis based upon the principles of mechanics. Extensive tests and experience with existing structures have shown that the requirements here stated will give adequate strength. See "Statical Limitations upon the Steel Requirement in Reinforced Concrete Flat Slab Floors," by John R. Nichols, *Transactions*, Am. Soc. Civil Engrs., Vol. LXXVII (1914), and "Moments and Stresses in Slabs," by Westergaard and Slater, *Proceedings*, Am. Concrete Inst., Vol. XVII (1921)

l = span length[1] of flat slab, center to center of columns in the rectangular direction in which moments are considered;

l_1 = span length[1] of flat slab, center to center of columns perpendicular to the rectangular direction in which moments are considered; and

W = total dead and live load uniformly distributed over a single panel area.

Table VI.—Moments to be Used in Design of Flat Slabs.[2]

Strip.	Flat Slabs without Dropped Panels.		Flat Slabs with Dropped Panels.	
	Negative.	Positive.	Negative.	Positive.
Slabs with 2-way Reinforcement.				
Column strip	$0.23\ M_0$	$0.11\ M_0$	$0.25\ M_0$	$0.10\ M_0$
2 Column strips	$0.46\ M_0$	$0.22\ M_0$	$0.50\ M_0$	$0.20\ M_0$
Middle strip	$0.16\ M_0$	$0.16\ M_0$	$0.15\ M_0$	$0.15\ M_0$
Slabs with 4-way Reinforcement.				
Column strip	$0.25\ M_0$	$0.10\ M_0$	$0.27\ M_0$	$0.095\ M_0$
2 Column strips	$0.50\ M_0$	$0.20\ M_0$	$0.54\ M_0$	$0.190\ M_0$
Middle strip	$0.10\ M_0$	$0.20\ M_0$	$0.08\ M_0$	$0.190\ M_0$

Principal Design Sections.

143. In computing the critical moments in flat slabs subjected to uniform load the following principal design sections shall be used:

(*a*) *Section for Negative Moment in Middle Strip:* The section beginning at a point on the edge of the panel $l_1/4$ from the column center and extending in a rectangular direction a distance $l_1/2$ toward the center of the adjacent column on the same panel edge. (See Fig. 15, Appendix 1.)

(*b*) *Section for Negative Moment in Column Strip:* The section beginning at a point on the edge of the panel $l_1/4$ from the center of a column and extending in a rectangular direction toward the column to a point $c/2$ therefrom and thence along a one-quarter circumference about the column center to the adjacent edge of the panel.

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[1] The column strip and the middle strip to be used when considering moments in the direction of the dimension l are located and dimensioned as shown in Fig. 15. The dimension l_1 does not always represent the short length of the panel. When moments in the direction of the shorter panel length are considered, the dimensions l and l_1 are to be interchanged and the strips corresponding to those shown in Fig. 15 but extending in the direction of the shorter panel length are to be considered.

[2] These are approximately the values which would be obtained by considering one-third of the total moment, M_0, as positive and two-thirds of it as negative moment.

(*c*) *Section for Positive Moment in Middle Strip:* The section of a length $l_1/2$ extending in a rectangular direction across the center of the middle strip.

(*d*) *Section for Positive Moment in Column Strip:* The section of length $l_1/4$ extending in a rectangular direction across the center of the column strip.

Moments in Principal Design Sections.

144. The moments in the principal design sections shall be those given in Table VI, except as follows:

(*a*) The sum of the maximum negative moments in the two column strips may be greater or less than the values given in Table VI by not more than 0.03 M_0.

(*b*) The maximum negative moment and the maximum positive moments in the middle strip and the sum of the maximum positive moments in the two column strips may each be greater or less than the values given in Table VI by not more than 0.01 M_0.

Thickness of Flat Slabs and Dropped Panels.

145. The total thickness,[1] t_1, of the dropped panel in inches, or of the slab if a dropped panel is not used, shall be not less than:

$$t_1 = 0.038\left(1 - 1.44\frac{c}{l}\right) l \sqrt{Rw'\frac{l_1}{b_1}} + 1\tfrac{1}{2} \dots\dots\dots (37)^2$$

where R = ratio of negative moment in the two column strips to M_0;

w' = uniformly distributed dead and live load per unit of area of floor; and

b_1 = dimension of the dropped panel in the direction parallel to l_1.

For slabs with dropped panels the total thickness[1] in inches at points beyond the dropped panel shall be not less than

$$t_2 = 0.02\, l \sqrt{w'} + 1 \dots\dots\dots\dots\dots (38)$$

The slab thickness t_1 or t_2 shall in no case be less than $l/32$ for floor slabs, and not less than $l/40$ for roof slabs. In determining minimum thickness by Formulas 37 and 38, the value of l shall be the panel length center to center of the columns, on long side of panel, l_1 shall be the panel length on the short side of the panel, and b_1 shall be the width or diameter of dropped panel in the direction of l_1, except that in a slab without dropped panel b_1 shall be 0.5 l_1.

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[1] The thickness will be in inches regardless of whether l and w' are in feet and pounds per square foot or in inches and pounds per square inch.

[2] The values of R used in this formula are the coefficients of M_0 for negative moment in two column strips in Table VI.

Minimum Dimensions of Dropped Panels.

146. The dropped panel shall have a length or diameter in each rectangular direction of not less than one-third the panel length in that direction, and a thickness not greater than 1.5 t_2.

Wall and Other Irregular Panels.

147. In wall panels and other panels in which the slab is discontinuous at the edge of the panel, the maximum negative moment one panel length away from the discontinuous edge and the maximum positive moment between shall be increased as follows:

(*a*) Column strip perpendicular to the wall or discontinuous edge, 15 per cent greater than that given in Table VI;

(*b*) Middle strip perpendicular to wall or discontinuous edge, 30 per cent greater than that given in Table VI.

In these strips the bars used for positive moments perpendicular to the discontinuous edge shall extend to the edge of the panel at which the slab is discontinuous.

Panels with Marginal Beams.

148. In panels having a marginal beam on one edge or on each of two adjacent edges, the beam shall be designed to carry at least the load superimposed directly upon it, exclusive of the panel load. A beam which has a depth greater than the thickness of the dropped panel into which it frames, shall be designed to carry, in addition to the load superimposed upon it, at least one-fourth of the distributed load for which the adjacent panel or panels are designed, and each column strip adjacent to and parallel with the beam shall be designed to resist a moment at least one-half as great as that specified in Table VI for a column strip.[1]

Each column strip adjacent to and parallel with a marginal beam which has a depth less than the thickness of the dropped panel into which it frames shall be designed to resist the moments specified in Table VI for a column strip. Marginal beams on opposite edges of a panel and the slab between them shall be designed for the entire load and the panels shall be designed as simple beams.

Discontinuous Panels.

149. The negative moments on sections at and parallel to the wall, or discontinuous edge of an interior panel, shall be determined by the conditions of restraint.[2]

Flat Slabs on Bearing Walls.

150. Where there is a beam or a bearing wall on the center line of columns in the interior portion of a continuous flat slab, the negative moment at the beam or wall line in the middle strip perpendicular to the beam or wall shall be taken as 30 per cent greater than the moment specified in Table VI for a middle strip. The column strip adjacent

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[1] In wall columns, brackets are sometimes substituted for capitals or other changes are made in the design of the capital. Attention is directed to the necessity for taking into account the change in the value of *c* in the moment formula for such cases.

[2] The committee is not prepared to make a more definite recommendation at this time.

to and lying on either side of the beam or wall shall be designed to resist a moment at least one-half of that specified in Table VI for a column strip.

Point of Inflection.

151. The point of inflection in any line parallel to a panel edge in interior panels of symmetrical slabs without dropped panels shall be assumed to be at a distance from the center of the span equal to three-tenths of the distance between the two sections of critical negative moment at opposite ends of the line; for slabs having dropped panels, the coefficient shall be 0.25.

Reinforcement.

152. The reinforcement bars which cross any section and which fulfill the requirements given in Section 153 may be considered as effective in resisting the moment at the section. The sectional area of a bar multiplied by the cosine of the angle between the direction of the axis of the bar and any other direction may be considered effective as reinforcement in that direction.

Arrangement of Reinforcement.

153. The design shall include adequate provision for securing the reinforcement in place so as to take not only the critical moments but the moments at intermediate sections. Provision shall be made for possible shifting of the point of inflection by carrying all bars in rectangular or diagonal directions, each side of a section of critical moment, either positive or negative, to points at least 20 diameters beyond the point of inflection as specified in Section 151. Lapped splices shall not be permitted at or near regions of maximum stress except as described above. At least four-tenths of all bars in each direction shall be of such length and shall be so placed as to provide reinforcement at two sections of critical negative moment and at the intermediate section of critical positive moment. Not less than one-third of the bars used for positive reinforcement in the column strip shall extend into the dropped panel not less than 20 diameters of the bar, or in case no dropped panel is used, shall extend to a point not less than one-eighth of the span length from the center line of the column or the support.

Reinforcement at Construction Joints.

154. See Section 72.

Tensile Stress in Reinforcement.

155. The tensile stress f_s in the reinforcement in flat slabs shall be taken as not less than that computed by Formula 39,

$$f_s = \frac{RM_0}{A_s jd} \qquad (39)$$

where RM_0 = moment specified in Section 144 for two column strips or for one middle strip; and

A_s = effective cross-sectional area of the reinforcement which crosses any of the principal design sections and which meets the requirements of Section 153.

The stress so computed shall not at any of the principal design sections exceed the values specified in Section 194.

Compressive Stress in Concrete.

156. The compressive stress in the concrete in flat slabs shall be taken as not less than that computed by Formulas 40 and 41, but the stress so computed shall not exceed $0.4f'_c$.

Compression due to negative moment, RM_0, in the two column strips,

$$f_c = \frac{3.5\,RM_0}{0.67\sqrt[3]{pn}\,b_1d^2}\left(1-1.2\,\frac{c}{l}\right)\ldots\ldots\ldots\ldots\ldots(40)$$

where b_1 is as specified in Section 145.

Compression due to positive moment, RM_0, in the two column strips, or negative or positive moment in the middle strip,

$$f_c = \frac{6\,RM_0}{0.67\sqrt[3]{pn}\,l_1d^2}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(41)$$

In special cases where supported by satisfactory engineering analysis, approved by the Engineer, compression reinforcement may be used to increase the resistance to compression in accordance with other provisions of these specifications.

Shearing Stress.

157. See Section 131.

Unusual Panels.

158. For structures having a width of one or two panels, and also for slabs having panels of markedly different sizes, an analysis shall be made of the moments developed in both slab and columns, and the values given in Sections 142 to 157 modified accordingly.

Bending Moments in Columns.

159. See Section 171.

G. Reinforced Concrete Columns.

Limiting Dimensions.

160. The following sections on reinforced concrete columns are based on the assumption of a short column. Where the unsupported length is greater than 40 times the least radius of gyration (40 R), the safe load shall be determined by Formula 47. Principal columns in buildings shall have a minimum diameter or thickness of 12 in. Posts that are not continuous from story to story shall have a minimum diameter or thickness of 6 in.

Unsupported Length.

161. The unsupported length of reinforced concrete columns shall be taken as:

(*a*) In flat slab construction the clear distance between the floor and under side of the capital;

(*b*) In beam-and-slab construction, the clear distance between the floor and the under side of the shallowest beam framing into the column at the next higher floor level;

(*c*) In floor construction with beams in one direction only, the clear distance between floor slabs;

(*d*) In columns supported laterally by struts or beams only, the clear distance between consecutive pairs (or groups) of struts or beams, provided that to be considered an adequate support, two such struts or beams shall meet the column at approximately the same level and the angle between the two planes formed by the axis of the column and the axis of each strut respectively is not less than 75 deg. nor more than 105 deg.

When haunches are used at the junction of beams or struts with columns, the clear distance between supports may be considered as reduced by two-thirds of the depth of the haunch.

Safe Load on Spiral Columns.

162. The safe axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall be not greater than that determined by Formula 42.

The symbols used in Formulas 42 to 49 are defined in Section 105, except as indicated in Sections 162, 165, 168, 170, 176 and 182.

$$P = A_c f_c + n f_c pA \quad \ldots\ldots\ldots\ldots (42)$$

where

P = total safe axial load on column whose h/R is less than 40;

A = area of the concrete core enclosed within the spiral; the diameter of the core (or of the spiral) shall be taken as the distance center to center of the spiral wire;

p = ratio of effective area of longitudinal reinforcement to area of the concrete core;

$A_c = A\ (1-p)$ = net area of concrete core; and

f_c = permissible compressive stress in concrete =

$$300+(0.10+4p)\,f'_c \quad \ldots\ldots\ldots\ldots (43)$$

The longitudinal reinforcement shall consist of at least six bars of minimum diameter of ½ in., and its effective cross-sectional area shall not be less than 1 per cent nor more than 6 per cent of that of the core.

Spiral Reinforcement.

163. The spiral reinforcement shall be not less than one-fourth the volume of the longitudinal reinforcement. It shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. The spacing of the spirals shall be not greater than one-sixth of the diameter of the core and in

no case more than 3 in. The spiral reinforcement shall meet the requirements of the Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement. (Appendix 7.)

Protection of Spirally Reinforced Column.

164. Reinforcement shall be protected everywhere by a covering of concrete cast monolithic with the core, which shall have a minimum thickness of $1\frac{1}{2}$ in. in square columns and 2 in. in round or octagonal columns.

Safe Load on Columns with Lateral Ties.

165. The safe axial load on columns reinforced with longitudinal bars and separate lateral ties shall be not greater than that determined by Formula 44,

$$P = (A'_c + A_s n) f_c \qquad (44)$$

where A'_c = net area of concrete in the column (total column area minus area of reinforcement);

A_s = effective cross-sectional area of longitudinal reinforcement; and

f_c = permissible compressive stress in concrete and shall not exceed $0.20f'_c$.

The amount of longitudinal reinforcement considered in the calculations shall be not more than 2 per cent nor less than 0.5 per cent of the total area of the column. The longitudinal reinforcement shall consist of not less than four bars of minimum diameter of $\frac{1}{2}$ in., placed with clear distance from the face of the column not less than 2 in.

Lateral Ties.

166. Lateral ties shall be not less than $\frac{1}{4}$ in. in diameter, spaced not more than 8 in. apart.

Bending in Columns.

167. Reinforced concrete columns subject to bending stresses shall be treated as follows:

(*a*) *With Spiral Reinforcement.*—The compressive unit stress on the concrete within the core area under combined axial load and bending shall not exceed by more than 20 per cent the value given for axial load by Formula 43.

(*b*) *With Lateral Ties.*—Additional longitudinal reinforcement may be used if required and the compressive unit stress on the concrete under combined axial load and bending may be increased to $0.30 f'_c$. The total amount of reinforcement considered in the computations shall be not more than 4 per cent of the total area of the column.

Tension in the longitudinal reinforcement due to bending of the column shall not exceed 16,000 lb. per sq. in.

Composite Columns.

168. The safe load on composite columns in which a structural steel or cast-iron column is thoroughly encased in a circumferentially reinforced concrete core shall be based on a certain unit stress for

the steel or cast-iron core plus a unit stress of $0.25 f'_c$ on the area within the spiral core.

The unit compressive stress on the steel section shall be not greater than that determined by Formula 45,

$$f_r = 18{,}000 - 70\, h/R \ldots\ldots\ldots\ldots\ldots (45)$$

but shall not exceed 16,000 lb. per sq. in.

The unit stress on the cast-iron section shall be not greater than that determined by Formula 46,

$$f_r = 12{,}000 - 60\, h/R \ldots\ldots\ldots\ldots\ldots (46)$$

but shall not exceed 10,000 lb. per sq. in.

In Formulas 45 and 46,

f_r = compressive unit stress in metal core, and

R = least radius of gyration of the steel or cast-iron section.

The diameter of the cast-iron section shall not exceed one-half of the diameter of the core within the spiral. The spiral reinforcement shall be not less than 0.5 per cent of the volume of the core within the spiral and shall conform in quality, spacing and other requirements to the provisions for spirals in Section 163.

Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams or girders. The area of the concrete between the spiral and the metal core shall be not less than that required to carry the total floor load of the story above on the basis of a stress in the concrete of $0.35 f'_c$, unless special brackets are arranged on the metal core to receive directly the beam or slab load.

Structural Steel Columns. 169. The safe load on a structural steel column of a section which fully encases an area of concrete, and which is protected by an outside shell of concrete at least 3 in. thick, shall be computed in the same manner as for composite columns in Section 168, allowing $0.25 f'_c$ on the area of the concrete enclosed by the steel section. The outside shell shall be reinforced by wire mesh, ties or spiral hoops weighing not less than 0.2 lb. per sq. ft. at the surface of the mesh and with a maximum spacing of 6 in. between strands or hoops. Special brackets shall be used to receive the entire floor load at each story. The safe load in steel columns calculated by Formula 45 shall not exceed 16,000 lb. per sq. in.

Long Columns. 170. The permissible working load on the core in axially loaded columns which have a length greater than 40 times the least radius of gyration of the column core (40 R) shall be not greater than that determined by Formula 47,

$$\frac{P'}{P} = 1.33 - \frac{h}{120\,R} \ldots\ldots\ldots\ldots\ldots (47)$$

where P' = total safe axial load on long column;
P = total safe axial load on column of the same section whose h/R is less than 40, determined as in Sections 162 and 165; and
R = least radius of gyration of column core.

Bending Moments in Columns.

171. The bending moments in interior and exterior columns shall be determined on the basis of loading conditions and end restraint, and shall be provided for in the design. The recognized methods shall be followed in calculating the stresses due to combined axial load and bending. In spiral columns the area to be considered as resisting the stress is the area within the spiral.

H. Footings.

General.

172. The requirements for tension, compression, shear and bond in Sections 103 and 141, inclusive, shall govern the design of footings, except as hereinafter provided.

Soil Footings.

173. The load per unit of area on soil footings shall be computed by dividing the column load by the area of base of the footing.

Pile Footings.

174. Footings on piles shall be treated in the same manner as footings on soil, except that the load shall be considered as concentrated at the pile centers.

Sloped or Stepped Footings.

175. Footings in which the thickness has been determined by the requirements for shear as specified in Sections 133 and 134 may be sloped or stepped between the critical section and the edge of the footing, provided that the shear on no section outside the critical section exceeds the value specified, and provided further that the thickness of the footing above the reinforcement at the edge shall not be less than 6 in. for footings on soil nor less than 12 in. for footings on piles. Sloped or stepped footings shall be cast as a unit.

Critical Section for Bending.

176. The critical section for bending in a concrete footing which supports a concrete column or pedestal, shall be considered to be at the face of the column or pedestal. Where steel or cast-iron column bases are used, the moment in the footing shall be computed at the middle and at the edge of the base; the load shall be considered as uniformly distributed over the column or pedestal base.

The bending moment at the critical section in a square footing supporting a concentric square column, shall be computed from the load on the trapezoid bounded by one face of the column, the corresponding outside edge of the footing, and the portions of the two diagonals. The load on the two corner triangles of this trapezoid shall be considered as applied at a distance from the face equal to six-tenths of the projection of the footing from the face of the column. The load on the rectangular portion of the trapezoid shall be considered as applied at its center of gravity. The bending moment is expressed by Formula 48,

$$M = \frac{w}{2}(a+1.2\,c)c^2 \ldots\ldots\ldots\ldots\ldots\ldots (48)$$

where M = bending moment at critical section of footing;
a = width of face of column or pedestal;
c = projection of footing from face of column; and
w = upward reaction per unit of area of base of footing.

For a round or octagonal column, the distance a shall be taken as equal to the side of a square of an area equal to the area enclosed within the perimeter of the column. (For typical footing designs, see Appendix 1, Figs. 16 and 17.)

Reinforcement.

177. The reinforcement in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth shall be the distance from the top of the footing to the plane of the reinforcement. The sectional area of reinforcement shall be distributed uniformly across the footing unless the width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread may be increased to include one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional reinforcement shall be placed outside of the width specified, but such reinforcement shall not be considered as effective in resisting the calculated bending moment. For the extra reinforcement a spacing double that within the effective belt may be used.

Concrete Stress.

178. The extreme fiber stress in compression in the concrete shall be kept within the limits specified in Section 189. The extreme fiber stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

Irregular Footings.

179. A rectangular or irregularly shaped footing shall be computed by dividing it into rectangles or trapezoids tributary to the sides of the column, using the distance to the center of gravity of the area as the moment arm of the upward forces. Outstanding portions of combined footings shall be treated in the same manner. Other portions of combined footings shall be designed as beams or slabs.

Shearing Stresses.

180. See Sections 132 to 134.

181. See Sections 135 to 141. **Bond Stress.**

182. The compressive stress in longitudinal reinforcement at the base of a column shall be transferred to the pedestal or footing by either dowels or distributing bases. When dowels are used, there shall be at least one for each column bar, and the total sectional area of the dowels shall be not less than the sectional area of the longitudinal reinforcement in the column. The dowels shall extend into the column and into the pedestal or footing not less than 50 diameters of the dowel bars for plain bars, or 40 diameters for deformed bars. **Transfer of Stress at Base of Column.**

When metal distributing bases are used, they shall have sufficient area and thickness to transmit safely the load from the longitudinal reinforcement in compression and bending. The permissible compressive unit stress on top of the pedestal or footing directly under the column shall be not greater than that determined by Formula 49,

$$r_a = 0.25\, f'_c \sqrt[3]{\frac{A}{A'}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (49)$$

where r_a = permissible working stress over the loaded area;
A = total area at the top of the pedestal or footing;
A' = loaded area at the column base;
f'_c = ultimate compressive strength of concrete. (See Section 120.)

In sloped or stepped footings A may be taken as the area of the top horizontal surface of the footing or as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base the loaded area A', and having side slopes of 1 vertical to 2 horizontal.

183. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal or on the minimum area of a pedestal footing shall not exceed $0.25\, f'_c$, unless reinforcement is provided and the member designed as a reinforced concrete column. **Pedestals Without Reinforcement.**

The depth of a pedestal or pedestal footing shall be not greater than three times its least width and the projection on any side from the face of the supported member shall be not greater than one-half the depth. The depth of a pedestal whose sides are sloped or stepped shall not exceed three times the least width or diameter of the section midway between the top and bottom. A pedestal footing supported directly on piles shall have a mat of reinforcing bars having a cross-sectional area of not less than 0.20 sq. in. per foot in each direction, placed 3 in. above the top of the piles.

I. Reinforced Concrete Retaining Walls.

Loads and Unit Stresses.

184. Reinforced concrete retaining walls shall be so designed[1] that the permissible unit stresses specified in Sections 186 to 197 are not exceeded. The heels of cantilever, counterforted and buttressed retaining walls shall be proportioned for maximum resultant vertical loads, but when the foundation reaction is neglected the permissible unit stresses shall not be more than 50 per cent greater than the normal permissible stresses.

Details of Design.

185. The following principles shall be followed in the design of reinforced concrete retaining walls:

(*a*) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the edge of the support.

(*b*) The vertical section of a cantilever wal shall be considered as a cantilever beam fixed at the top of the base.

(*c*) The vertical sections of counterforted and buttressed walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements for a continuous slab in Section 110.

(*d*) The exposed faces of walls without buttresses shall preferably be given a batter of not less than $\frac{1}{4}$ in. per ft.

(*e*) Counterforts shall be designed in accordance with the requirements for T-beams in Sections 113 to 115. Stirrups shall be provided in the counterforts to take the reaction when the tension reinforcement of the face walls and heels of bases is designed to span between the counterforts. Stirrups shall be anchored as near the exposed face of the longitudinal wall and as close to the lower face of the base as the requirements for protective covering permit.

(*f*) Buttresses shall be designed in accordance with the requirements specified for rectangular beams.

(*g*) The shearing stress at the junction of the base with counterforts or buttresses shall not exceed the values specified in Sections 120 to 130.

(*h*) Horizontal metal reinforcement shall be of such form and so distributed as to develop the required bond. To prevent temperature and shrinkage cracks in exposed surface not less than 0.25 sq. in. of horizontal metal reinforcement per foot of height shall be provided.

(*i*) Grooved lock joints shall be placed not over 60 ft. apart to care for temperature changes.

(*j*) Counterforts and buttresses shall be located under all points of concentrated loading, and at intermediate points, as may be required by the design.

---

[1] In proportioning retaining walls consideration should be given to:
(*a*) Bearing value of soil;
(*b*) Stability against sliding.

(*k*) The walls shall be cast as a unit between expansion joints, unless construction joints formed in accordance with Sections 69 and 73 are provided.

(*l*) Drains or "weep holes" not less than 4 in. in diameter and not more than 10 ft. apart, shall be provided. At least one drain shall be provided for each pocket formed by counterforts.

J. Summary of Working Stresses.

General.

186. The following working stresses shall be used:
where, f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 13) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 12).

Direct Stress in Concrete.

Direct Compression.

187. (*a*) Columns whose length does not exceed $40R$:
   (1) With spirals .... varies with amount of longitudinal reinforcement. (See Section 162.)
   (2) Longitudinal reinforcement and lateral ties. (See Section 165.)
(*b*) Long columns .... (See Section 170.)
(*c*) Piers and Pedestals .... $0.25f'_c$
   (See Section 183.)

Compression in Extreme Fiber.

188. (*a*) Extreme fiber stress in flexure .... $0.40f'_c$
(*b*) Extreme fiber stress in flexure adjacent to supports of continuous beams .... $0.45f'_c$

Tension.

189. In Concrete Members .... None

Shearing Stresses in Concrete.

Longitudinal Bars without Special Anchorage.

190. (*a*) Beams without web reinforcement .... $0.02f'_c$
(*b*) Beams with stirrups or bent-up bars or combination of the two .... $0.06f'_c$

Longitudinal Bars Having Special Anchorage.

191. (*a*) Beams without web reinforcement .... $0.03f'_c$
(*b*) Beams with stirrups or bent-up bars or a combination of the two .... $0.12f'_c$

Flat Slabs.

192. (*a*) Shear at distance *d* from capital or dropped panel ... $0.03f'_c$
(*b*) Other limiting cases in flat slabs. (See Section 131.)

Footings.

193. (*a*) Longitudinal bars without special anchorage .... $0.02f'_c$
(*b*) Longitudinal bars having special anchorage .... $0.03f'_c$

Stresses in Reinforcement.

Tension in Steel.

194. (*a*) Billet-steel bars:
(1) Structural steel grade .... 16,000 lb. per sq. in.
(2) Intermediate grade .... 18,000 " "
(3) Hard grade .... 18,000 " "
(*b*) Rail-steel bars .... 18,000 " "
(*c*) Structural steel .... 16,000 " "
(*d*) Cold-drawn steel wire:
(1) Spirals .... Stress not calculated
(2) Elsewhere .... 18,000 lb. per sq. in.

Compression in Steel.

195. (*a*) Bars .... same as Section 194 (*a*) and (*b*)
(*b*) Structural steel core of composite column .... 16,000 lb. per sq. in.
reduced for slenderness ratio .... (see Section 168)
(*c*) Structural steel column .... 16,000 lb. per sq. in.
reduced for slenderness ratio .... (see Section 169)

Compression in Cast Iron.

196. Composite cast-iron column .... 10,000 lb. per sq. in.
reduced for slenderness ratio .... (see Section 168)

Bond Between Concrete and Reinforcement.

197. (*a*) Beams and slabs, plain bars .... $0.04f'_c$
(*b*) Beams and slabs, deformed bars .... $0.05f'_c$
(*c*) Footings, plain bars, one-way .... $0.04f'_c$
(*d*) Footings, deformed bars, one way .... $0.05f'_c$
(*e*) Footings, bars two ways .... (*c*) or (*d*) reduced by 25 per cent

MANDATORY APPENDICES

APPENDIX 1

NOTATIONS AND FIGURES

All symbols used in the Standard Specifications for Concrete and Reinforced Concrete have been collected here for convenience of reference. The symbols are in general defined in the text near the formulas in which they are used. In a few instances the same symbol is used in two distinct senses; however, there is little danger of confusion from this source.

NOTATION

a = width of face of column or pedestal;

α = angle between inclined web bars and longitudinal bars;

A = total net area of column, footing, or pedestal, exclusive of fireproofing;

A' = loaded area of pedestal, pier or footing;

A_c = $A(1-p)$ = net area of concrete core of column (core area minus reinforcement);

A'_c = net area of concrete in columns with lateral ties (total column area minus area of reinforcement);

A_s = effective cross-sectional area of metal reinforcement in tension in beams or compression in columns; and the effective cross-sectional area of metal reinforcement which crosses any of the principal design sections of a flat slab and which meets the requirements of Section 153;

A_v = total area of web reinforcement in tension within a distance of s (s_1, s_2, s_3, etc.) or the total area of all bars bent up in any one plane (see Fig. 9);

b = width of rectangular beam or width of flange of T-beam;

b' = width of stem of T-beam;

b_1 = dimension of the dropped panel of a flat slab in the direction parallel to l_1;[1]

c = base diameter of the largest right circular cone which lies entirely within the column (including the capital) whose vertex angle is 90 deg. and whose base is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (see Fig. 14);

c = projection of footing from face of column;

C = total compressive stress in concrete;

---

[1] In flat slab design, the column strip and the middle strip to be used when considering moments in the direction of the dimension l are located and dimensioned as shown in Fig. 15. The dimension l_1 does not always represent the short length of the panel. When moments in the direction of the shorter panel length are considered, the dimensions l and l_1 are to be interchanged and strips corresponding to those shown in Fig. 15 but extending in the direction of the shorter panel length are to be considered.

C' = total compressive stress in reinforcement;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

E_c = modulus of elasticity of concrete in compression;

E_s = modulus of elasticity of steel in tension = 30,000,000 lb. per sq. in.;

f_c = compressive unit stress in extreme fiber of concrete;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 13) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 12);

f_r = compressive unit stress in metal core;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

f_v = tensile unit stress in web reinforcement;

F = total tension in a bar;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

jd = $d-z$ = arm of resisting couple;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from center to center of supports; for special cases, see Sections 106 and 145);

l = span length of flat slab, center to center of columns, in the rectangular direction in which moments are considered;[1]

l_1 = span length of flat slab, center to center of columns, perpendicular to the rectangular direction in which moments are considered;[1]

M = bending moment or moment of resistance in general;

M_0 = sum of positive and negative bending moments in either rectangular direction, at the principal design sections of a panel of a flat slab;

n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;

Σo = sum of perimeters of bars in one set;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams $= A_s/bd$; and the ratio of effective area of longitudinal reinforcement to the area of the concrete core in columns;

---

[1] See footnote regarding b_1 in foregoing notation, p. 367.

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

P = total safe axial load on column whose h/R is less than 40;

P' = total safe axial load on long column;

Q = ratio of the average to the maximum bond stress computed by Formula 34 within the distance y;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

r_a = permissible working stress in concrete over the loaded area of a pedestal, pier or footing;

R = ratio of positive or negative moment in two column strips or one middle strip of a flat slab, to M_0;

R = least radius of gyration of a section;

s = spacing of web members, measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam;

t = thickness of flange of T-beam;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel (see Fig. 14);

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel (see Fig 14);

T = total tensile stress in longitudinal reinforcement;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

w = uniformly distributed load per unit of length of beam or slab;

w = upward reaction per unit of area of base of footing;

w' = uniformly distributed dead and live load per unit of area of a floor or roof;

W = total dead and live load uniformly distributed over a single panel area;

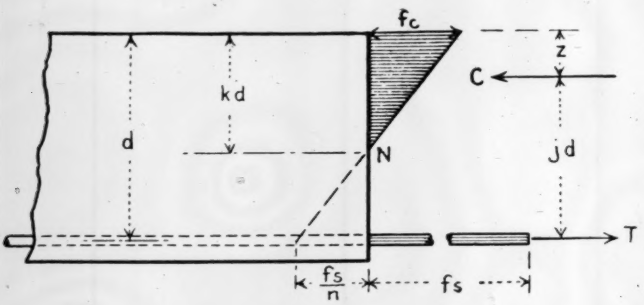
x = length of bar added for anchorage, including the hook, if any;

y = distance from the point at which the tension is computed to the point of beginning of anchorage;

z = depth from compression surface of beam or slab to resultant of compressive stresses.

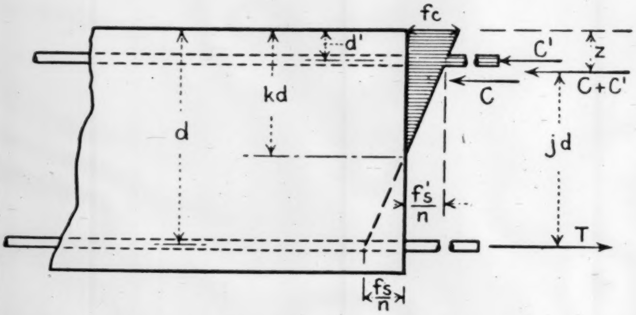
FIGURES.

For explanation of symbols used in figures, see foregoing notation.



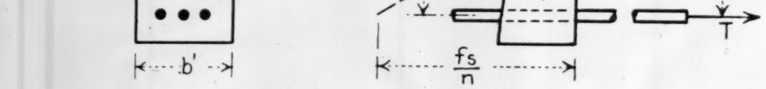
fc
z
C
kd
d
N
jd
T
fs/n
fs

FIG. 1.—Nomenclature for Concrete Beam Reinforced for Tension.



fc
d'
C'
z
C+C'
C
kd
d
jd
f's/n
T
fs/n

FIG. 2.—Nomenclature for Concrete Beam Reinforced for Tension and Compression.



b
t
kd
d
fc
z
jd
T
b'
fs/n

FIG. 3.—Nomenclature for Reinforced Concrete T-Beam.

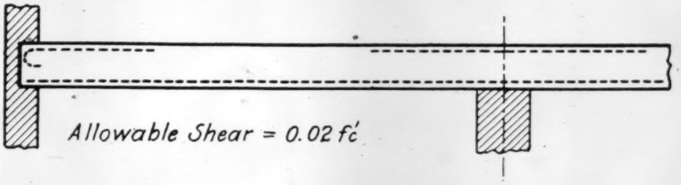

Allowable Shear = 0.02 f'c

FIG. 4.—Typical Reinforced Concrete Beam; Principal Longitudinal Bars without Special Anchorage.

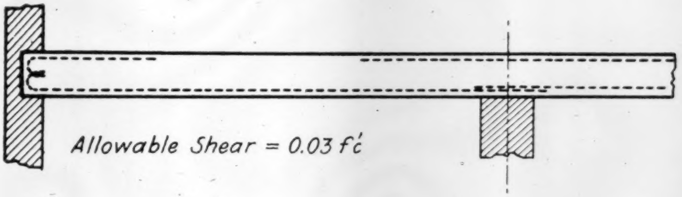

Allowable Shear = 0.03 f'c

FIG. 5.—Typical Reinforced Concrete Beam; Special Anchorage of Longitudinal Bars.

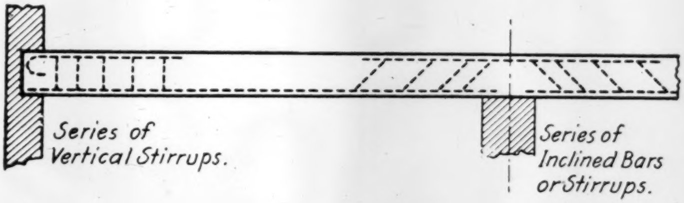

Series of
Vertical Stirrups.
Series of
Inclined Bars
or Stirrups.

FIG. 6.—Typical Reinforced Concrete Beam without Special Anchorage; Web Reinforced by Means of Series of Vertical Stirrups or Series of Inclined Bars or Stirrups.

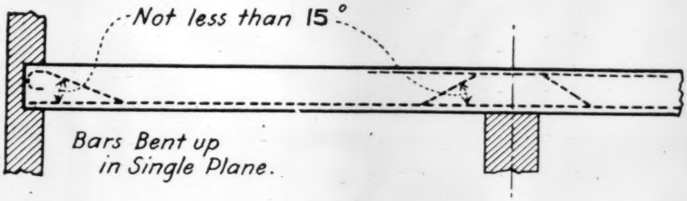

Not less than 15°
Bars Bent up
in Single Plane.

FIG. 7.—Typical Reinforced Concrete Beam; Principal Longitudinal Bars Bent up in Single Plane.

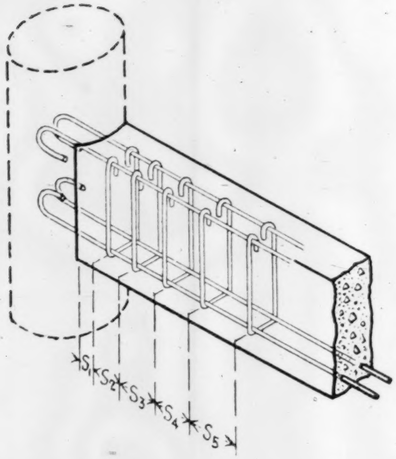
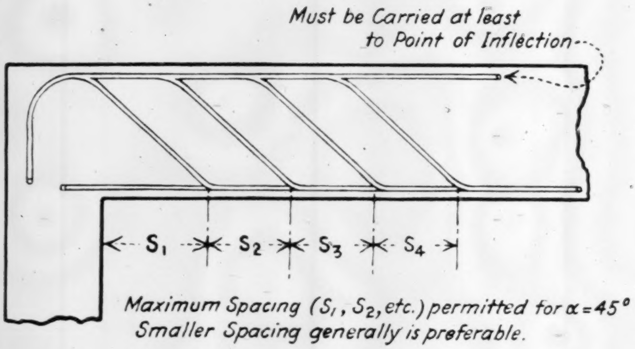


FIG. 8.—Typical Reinforced Concrete Beam with Anchored Longitudinal Bars and Vertical Stirrups.


Must be Carried at least to Point of Inflection

Maximum Spacing (S_1, S_2, etc.) permitted for $\alpha = 45°$
Smaller Spacing generally is preferable.

FIG. 9.—Typical Beam with Web Reinforced by Means of Series of Inclined Bars.

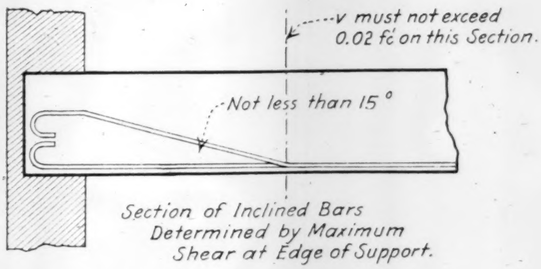

v must not exceed
0.02 f'c on this Section.
Not less than 15°
Section of Inclined Bars
Determined by Maximum
Shear at Edge of Support.

FIG. 10.—Typical Beam with Web Reinforced by Means of Bars Bent up in Single Plane.

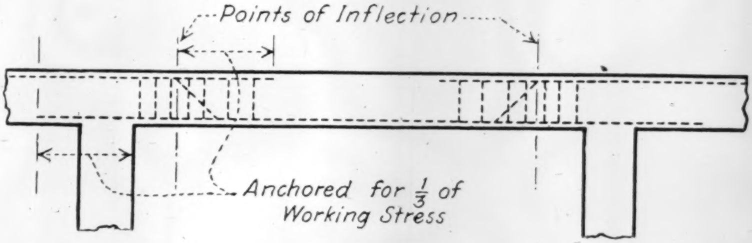

Points of Inflection
Anchored for $\frac{1}{3}$ of
Working Stress

FIG. 11.—Typical Web Reinforcement for Continuous Beams with Special Anchorages.

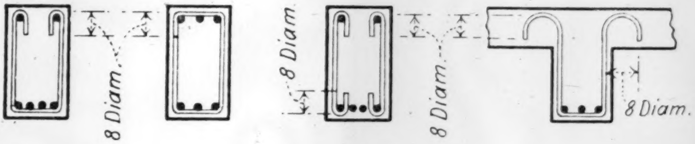

8 Diam.
8 Diam.
8 Diam.
8 Diam.

FIG. 12.—Typical Methods of Anchoring Vertical Stirrups.

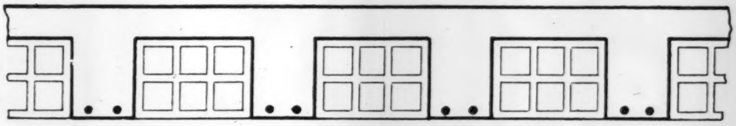


FIG. 13.—Typical Reinforced Concrete Beam-and-Tile Construction.

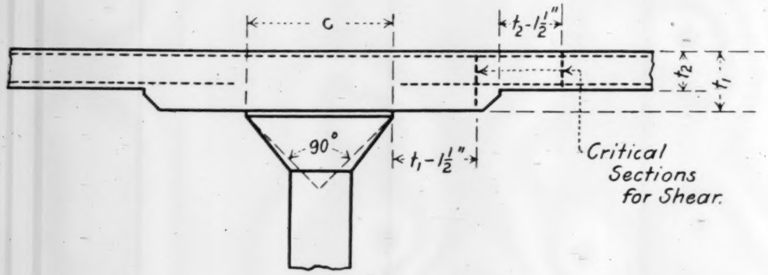

c
t2-1½"
t2
t1
90°
t1-1½"
Critical Sections for Shear.

FIG. 14.—Typical Column Capital and Sections of Flat Slab with Dropped Panel.

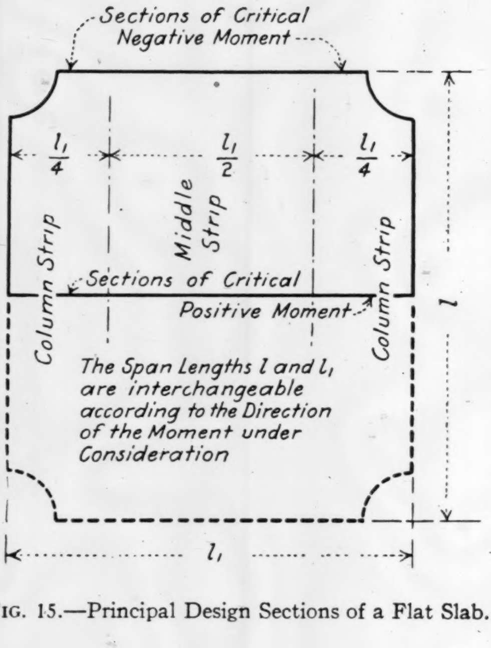
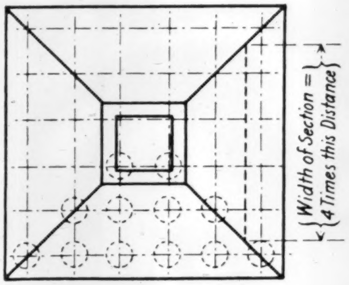
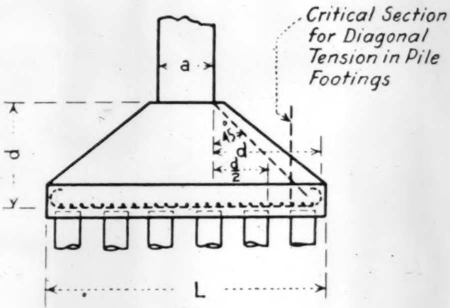

Sections of Critical Negative Moment
l1/4
l1/2
l1/4
Middle Strip
Column Strip
Column Strip
Sections of Critical Positive Moment
l
The Span Lengths l and l1 are interchangeable according to the Direction of the Moment under Consideration
l1

FIG. 15.—Principal Design Sections of a Flat Slab.


Width of Section = 4 Times this Distance

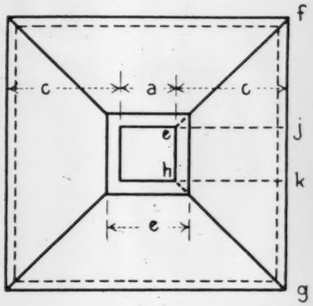
(a)
Plan.


Critical Section for Diagonal Tension in Pile Footings

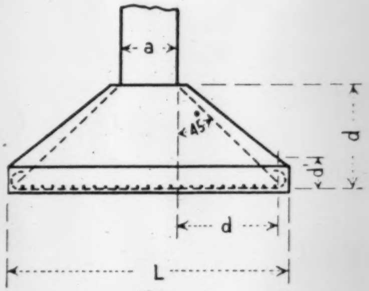
a
d
45°
d
$\frac{d}{2}$
L

(b)
Elevation.

FIG. 16.—Typical Sloped Reinforced Concrete Footing on Piles.


f
c
a
c
j
e
h
k
e
g

(a)
Plan.


a
45°
d
$\frac{d}{2}$
d
L

(b)
Elevation.

FIG. 17.—Typical Sloped Reinforced Concrete Footing on Soil.

APPENDIX 16.

PROPORTIONS[1] FOR CONCRETE OF GIVEN COMPRESSIVE STRENGTH AT 28 DAYS.

The table gives the proportions in which portland cement and a wide range in sizes of fine and coarse aggregates should be mixed to obtain concrete of compressive strengths ranging from 1500 to 3000 lb. per sq. in. at 28 days. Proportions are given for concrete of four different consistencies.

The purpose of the table is twofold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-face type shall be used.

The use of this table as a guide in the selection of concrete mixtures is based on the following:

(1) Concrete shall be plastic;

(2) Aggregates shall be clean and structurally sound;

(3) Aggregates shall be graded between the sizes indicated;

(4) Cement shall conform to the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9–21) of the American Society for Testing Materials. (Appendix 2.)

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the Tentative Method of Test for Consistency of Portland-Cement Concrete for Pavements or for Pavement Base (Serial Designation: D 138 – 22 T) of the American Society for Testing Materials. (Appendix 11.)

Apply the following rules in determining the size assigned to a given aggregate:

(1) Not less than 15 per cent shall be retained between the sieve which is considered the maximum size[2] and the next smaller sieve.

(2) Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size.[2]

(3) Only the sieve sizes given in the table shall be considered in applying rules (1) and (2).

(4) Sieve analysis shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41–24) of the American Society for Testing Materials. (Appendix 8.)

Proportions may be interpolated for concrete strengths, aggregate sizes and consistencies not covered by the table or determined by test.

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[1] Based on the 28-day compressive strengths of 6 by 12-in. cylinders, made and stored in accordance with the Tentative Methods of Making Compression Tests of Concrete (Serial Designation: C 39 – 21 T) of the American Society for Testing Materials. (Appendix 12.)

[2] For example: a graded sand with 16 per cent retained on the No. 8 sieve would fall in the 0-No. 4 size; if 14 per cent or less were retained, the sand would fall in the 0-No. 8 size. A coarse aggregate having 16 per cent coarser than 2-in. sieve would be considered as 3-in. aggregate.

PROPORTIONS FOR 1500 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
			0 – No. 14	0 – No. 8	0 – No. 4	0 – $\frac{3}{8}$ in.
None	$\frac{1}{2}$ to 1	1 : 2.8	1 : 3.2	1 : 3.8	1 : 4.4	1 : 5.1
	3 " 4	1 : 2.4	1 : 2.8	1 : 3.3	1 : 3.8	1 : 4.5
	6 " 7	**1 : 1.9**	**1 : 2.2**	**1 : 2.6**	**1 : 3.0**	**1 : 3.6**
	8 " 10	1 : 1.4	1 : 1.6	1 : 1.8	1 : 2.1	1 : 2.5
No. 4 to $\frac{3}{4}$ in.	$\frac{1}{2}$ to 1	1 : 2.6 : 4.6	1 : 2.9 : 4.3	1 : 3.4 : 4.1	1 : 3.9 : 3.6	1 : 4.6 : 3.1
	3 " 4	1 : 2.3 : 4.0	1 : 2.6 : 3.8	1 : 2.9 : 3.6	1 : 3.4 : 3.2	1 : 4.1 : 2.8
	6 " 7	**1 : 1.8 : 3.4**	**1 : 2.0 : 3.2**	**1 : 2.3 : 3.1**	**1 : 2.6 : 2.8**	**1 : 3.1 : 2.5**
	8 " 10	1 : 1.1 : 2.5	1 : 1.3 : 2.4	1 : 1.5 : 2.4	1 : 1.7 : 2.2	1 : 2.1 : 2.0
No. 4 to 1 in.	$\frac{1}{2}$ to 1	1 : 2.4 : 5.3	1 : 2.7 : 5.2	1 : 3.1 : 5.0	1 : 3.5 : 4.7	1 : 4.3 : 4.3
	3 " 4	1 : 2.1 : 4.7	1 : 2.4 : 4.5	1 : 2.7 : 4.4	1 : 3.1 : 4.1	1 : 3.7 : 3.7
	6 " 7	**1 : 1.6 : 3.9**	**1 : 1.8 : 3.8**	**1 : 2.1 : 3.7**	**1 : 2.4 : 3.5**	**1 : 2.9 : 3.3**
	8 " 10	1 : 1.1 : 2.9	1 : 1.2 : 2.8	1 : 1.4 : 2.8	1 : 1.6 : 2.7	1 : 1.9 : 2.5
No. 4 to $1\frac{1}{2}$ in.	$\frac{1}{2}$ to 1	1 : 2.4 : 6.0	1 : 2.7 : 5.9	1 : 3.1 : 5.8	1 : 3.5 : 5.4	1 : 4.1 : 5.1
	3 " 4	1 : 2.0 : 5.4	1 : 2.3 : 5.3	1 : 2.7 : 5.2	1 : 3.0 : 5.0	1 : 3.5 : 4.6
	6 " 7	**1 : 1.6 : 4.4**	**1 : 1.8 : 4.3**	**1 : 2.0 : 4.3**	**1 : 2.3 : 4.1**	**1 : 2.7 : 3.9**
	8 " 10	1 : 1.0 : 3.3	1 : 1.1 : 3.2	1 : 1.3 : 3.2	1 : 1.5 : 3.1	1 : 1.8 : 2.9
No. 4 to 2 in.	$\frac{1}{2}$ to 1	1 : 2.2 : 6.9	1 : 2.4 : 6.8	1 : 2.8 : 6.8	1 : 3.1 : 6.6	1 : 3.7 : 6.4
	3 " 4	1 : 1.8 : 6.2	1 : 2.0 : 6.1	1 : 2.4 : 6.1	1 : 2.7 : 6.0	1 : 3.1 : 5.7
	6 " 7	**1 : 1.4 : 5.1**	**1 : 1.6 : 5.0**	**1 : 1.8 : 5.0**	**1 : 2.0 : 5.0**	**1 : 2.4 : 4.8**
	8 " 10	1 : 0.9 : 3.8	1 : 1.0 : 3.8	1 : 1.1 : 3.8	1 : 1.3 : 3.8	1 : 1.5 : 3.7
$\frac{3}{8}$ to 1 in.	$\frac{1}{2}$ to 1	1 : 2.8 : 5.2	1 : 3.1 : 5.1	1 : 3.6 : 4.8	1 : 4.2 : 4.6	1 : 4.8 : 4.1
	3 " 4	1 : 2.4 : 4.5	1 : 2.6 : 4.5	1 : 3.1 : 4.3	1 : 3.6 : 4.0	1 : 4.1 : 3.6
	6 " 7	**1 : 1.9 : 3.9**	**1 : 2.1 : 3.7**	**1 : 2.4 : 3.6**	**1 : 2.8 : 3.4**	**1 : 3.2 : 3.1**
	8 " 10	1 : 1.3 : 2.8	1 : 1.4 : 2.8	1 : 1.6 : 2.7	1 : 1.9 : 2.6	1 : 2.2 : 2.4
$\frac{3}{8}$ to $1\frac{1}{2}$ in.	$\frac{1}{2}$ to 1	1 : 2.8 : 5.8	1 : 3.1 : 5.7	1 : 3.5 : 5.5	1 : 4.1 : 5.3	1 : 4.7 : 4.9
	3 " 4	1 : 2.4 : 5.2	1 : 2.7 : 5.1	1 : 3.1 : 5.0	1 : 3.5 : 4.8	1 : 4.1 : 4.4
	6 " 7	**1 : 1.9 : 4.3**	**1 : 2.1 : 4.2**	**1 : 2.4 : 4.2**	**1 : 2.7 : 4.0**	**1 : 3.1 : 3.7**
	8 " 10	1 : 1.2 : 3.2	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.8 : 3.0	1 : 2.1 : 2.9
$\frac{3}{8}$ to 2 in.	$\frac{1}{2}$ to 1	1 : 2.7 : 6.6	1 : 3.0 : 6.6	1 : 3.4 : 6.5	1 : 3.9 : 6.4	1 : 4.4 : 6.0
	3 " 4	1 : 2.3 : 5.9	1 : 2.6 : 5.9	1 : 2.9 : 5.8	1 : 3.3 : 5.6	1 : 3.7 : 5.5
	6 " 7	**1 : 1.8 : 4.9**	**1 : 2.0 : 4.8**	**1 : 2.2 : 4.8**	**1 : 2.6 : 4.8**	**1 : 3.0 : 4.5**
	8 " 10	1 : 1.2 : 3.7	1 : 1.3 : 3.7	1 : 1.5 : 3.7	1 : 1.7 : 3.6	1 : 1.9 : 3.5
$\frac{3}{4}$ to $1\frac{1}{2}$ in.	$\frac{1}{2}$ to 1	1 : 3.2 : 5.4	1 : 3.6 : 5.3	1 : 4.1 : 5.1	1 : 4.7 : 4.8	1 : 5.3 : 4.4
	3 " 4	1 : 2.8 : 4.8	1 : 3.2 : 4.8	1 : 3.6 : 4.6	1 : 4.0 : 4.4	1 : 4.6 : 4.0
	6 " 7	**1 : 2.1 : 4.0**	**1 : 2.5 : 4.0**	**1 : 2.8 : 3.9**	**1 : 3.2 : 3.7**	**1 : 3.5 : 3.4**
	8 " 10	1 : 1.5 : 3.0	1 : 1.7 : 3.0	1 : 1.9 : 2.9	1 : 2.2 : 2.8	1 : 2.5 : 2.7
$\frac{3}{4}$ to 2 in.	$\frac{1}{2}$ to 1	1 : 3.2 : 6.2	1 : 3.6 : 6.1	1 : 4.0 : 6.0	1 : 4.6 : 5.8	1 : 5.2 : 5.4
	3 " 4	1 : 2.8 : 5.5	1 : 3.1 : 5.5	1 : 3.5 : 5.4	1 : 3.9 : 5.2	1 : 4.5 : 4.9
	6 " 7	**1 : 2.1 : 4.5**	**1 : 2.4 : 4.6**	**1 : 2.7 : 4.5**	**1 : 3.1 : 4.4**	**1 : 3.5 : 4.1**
	8 " 10	1 : 1.4 : 3.4	1 : 1.6 : 3.4	1 : 1.8 : 3.4	1 : 2.1 : 3.4	1 : 2.4 : 3.3
$\frac{3}{4}$ to 3 in.	$\frac{1}{2}$ to 1	1 : 3.2 : 7.1	1 : 3.6 : 7.1	1 : 4.0 : 7.0	1 : 4.6 : 6.9	1 : 5.2 : 6.6
	3 " 4	1 : 2.7 : 6.3	1 : 3.0 : 6.3	1 : 3.4 : 6.3	1 : 4.0 : 6.2	1 : 4.5 : 5.9
	6 " 7	**1 : 2.1 : 5.1**	**1 : 2.4 : 5.2**	**1 : 2.7 : 5.2**	**1 : 3.1 : 6.1**	**1 : 3.5 : 4.9**
	8 " 10	1 : 1.4 : 3.8	1 : 1.6 : 3.9	1 : 1.8 : 3.9	1 : 2.1 : 3.9	1 : 2.4 : 3.8

PROPORTIONS FOR 2000 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : **Fine Aggregate : Coarse Aggregate**

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None.............	½ to 1	1 : 2.2	1 : 2.6	1 : 3.0	**1 : 3.5**	**1 . 4.1**
	3 " 4	1 : 1.9	1 : 2.2	1 : 2.6	**1 : 3.0**	**1 : 3.5**
	6 " 7	**1 : 1.5**	**1 : 1.7**	**1 : 2.0**	**1 : 2.3**	**1 : 2.7**
	8 "10	**1 : 1.0**	**1 : 1.1**	**1 : 1.3**	1 : 1.6	1 : 1.8
No. 4 to ¾ in.......	½ to 1	1 : 2.1 : 3.8	1 : 2.3 : 3.7	1 : 2.6 : 3.5	1 : 3.0 : 3.1	1 : 3.6 : 2.8
	3 " 4	1 : 1.7 : 3.3	1 : 1.9 : 3.2	1 : 2.2 : 3.1	1 : 2.6 : 2.8	1 : 3.0 : 2.4
	6 " 7	**1 : 1.3 : 2.7**	**1 : 1.4 : 2.6**	**1 : 1.7 : 2.5**	**1 : 1.9 : 2.3**	**1 : 2.3 : 2.1**
	8 "10	1 : 0.8 : 1.9	1 : 0.9 : 1.9	1 : 1.0 : 1.8	1 : 1.2 : 1.7	1 : 1.5 : 1.6
No. 4 to 1 in.......	½ to 1	1 : 1.9 : 4.5	1 : 2.2 : 4.3	1 : 2.5 : 4.2	1 : 2.8 : 3.9	1 : 3.4 : 3.6
	3 " 4	1 : 1.6 : 3.9	1 : 1.8 : 3.8	1 : 2.1 : 3.7	1 : 2.4 : 3.5	1 : 2.8 : 3.2
	6 " 7	**1 : 1.2 : 3.1**	**1 : 1.3 : 3.1**	**1 : 1.5 : 3.0**	**1 : 1.8 : 2.9**	**1 : 2.1 : 2.7**
	8 "10	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 1.0 : 2.3	1 : 1.1 : 2.1	1 : 1.3 : 2.0
No. 4 to 1½ in......	½ to 1	1 : 1.9 : 5.0	1 : 2.1 : 4.9	1 : 2.4 : 4.9	1 : 2.7 : 4.6	1 : 3.2 : 4.4
	3 " 4	1 : 1.6 : 4.4	1 : 1.7 : 4.3	1 : 2.0 : 4.2	1 : 2.4 : 4.0	1 : 2.7 : 3.8
	6 " 7	**1 : 1.1 : 3.5**	**1 : 1.3 : 3.5**	**1 : 1.4 : 3.5**	**1 : 1.7 : 3.4**	**1 : 2.0 : 3.2**
	8 "10	1 : 0.7 : 2.5	1 : 0.8 : 2.5	1 : 0.9 : 2.5	1 : 1.0 : 2.4	1 : 1.2 : 2.3
No. 4 to 2 in.......	½ to 1	1 : 1.7 : 5.8	1 : 1.9 : 5.7	1 : 2.1 : 5.8	1 : 2.4 : 5.6	1 : 2.8 : 5.5
	3 " 4	1 : 1.4 : 5.0	1 : 1.5 : 5.0	1 : 1.8 : 5.0	1 : 2.0 : 4.9	1 : 2.3 : 4.7
	6 " 7	**1 : 1.0 : 4.1**	**1 : 1.1 : 4.1**	**1 : 1.2 : 4.1**	**1 : 1.4 : 4.1**	**1 : 1.7 : 3.9**
	8 "10	1 : 0.6 : 2.9	1 : 0.7 : 2.9	1 : 0.7 : 3.0	1 : 0.8 : 2.9	1 : 1.0 : 2.9
⅜ to 1 in..........	½ to 1	1 : 2.2 : 4.4	1 : 2.5 : 4.2	1 : 2.8 : 4.1	1 : 3.3 : 3.8	1 : 3.8 : 3.4
	3 " 4	1 : 1.9 : 3.8	1 : 2.1 : 3.7	1 : 2.4 : 3.6	1 : 2.8 : 3.4	1 : 3.2 : 3.1
	6 " 7	**1 : 1.4 : 3.1**	**1 : 1.5 : 3.0**	**1 : 1.8 : 3.0**	**1 : 2.1 : 2.8**	**1 : 2.4 : 2.5**
	8 "10	1 : 0.9 : 2.2	1 : 1.0 : 2.2	1 : 1.1 : 2.2	1 : 1.3 : 2.0	1 : 1.5 : 1.9
⅜ to 1½ in.........	½ to 1	1 : 2.2 : 4.9	1 : 2.5 : 4.8	1 : 2.8 : 4.7	1 : 3.2 : 4.6	1 : 3.7 : 4.2
	3 " 4	1 : 1.9 : 4.3	1 : 2.1 : 4.2	1 : 2.4 : 4.1	1 : 2.7 : 4.0	1 : 3.1 : 3.7
	6 " 7	**1 : 1.4 : 3.5**	**1 : 1.5 : 3.4**	**1 : 1.7 : 3.4**	**1 : 2.0 : 3.3**	**1 : 2.3 : 3.1**
	8 "10	1 : 0.9 : 2.5	1 : 1.0 : 2.5	1 : 1.1 : 2.4	1 : 1.3 : 2.4	1 : 1.5 : 2.3
⅜ to 2 in..........	½ to 1	1 : 2.1 : 5.6	1 : 2.3 : 5.5	1 : 2.6 : 5.5	1 : 3.0 : 5.4	1 : 3.5 : 5.1
	3 " 4	1 : 1.7 : 4.8	1 : 2.0 : 4.8	1 : 2.2 : 4.8	1 : 2.5 : 4.7	1 : 2.9 : 4.4
	6 " 7	**1 : 1.3 : 4.0**	**1 : 1.4 : 3.9**	**1 : 1.6 : 3.9**	**1 : 1.8 : 3.9**	**1 : 2.1 : 3.8**
	8 "10	1 : 0.8 : 2.9	1 : 0.9 : 2.9	1 : 1.0 : 2.9	1 : 1.2 : 2.9	1 : 1.3 : 2.8
¾ to 1½ in.........	½ to 1	1 : 2.6 : 4.5	1 : 2.9 : 4.5	1 : 3.3 : 4.4	1 : 3.8 : 4.2	1 : 4.3 : 3.9
	3 " 4	1 : 2.2 : 3.9	1 : 2.5 : 3.9	1 : 2.8 : 3.8	1 : 3.2 : 3.6	1 : 3.6 : 3.3
	6 " 7	**1 : 1.6 : 3.2**	**1 : 1.8 : 3.2**	**1 : 2.1 : 3.1**	**1 : 2.4 : 3.0**	**1 : 2.7 : 2.8**
	8 "10	1 : 1.0 : 2.3	1 : 1.2 : 2.3	1 : 1.4 : 2.2	1 : 1.6 : 2.2	1 : 1.8 : 2.1
¾ to 2 in..........	½ to 1	1 : 2.5 : 5.2	1 : 2.8 : 5.2	1 : 3.2 : 5.1	1 : 3.6 : 5.0	1 : 4.1 : 4.7
	3 " 4	1 : 2.1 : 4.5	1 : 2.4 : 4.5	1 : 2.7 : 4.4	1 : 3.1 : 4.3	1 : 3.5 : 4.0
	6 " 7	**1 : 1.6 : 3.7**	**1 : 1.8 : 3.7**	**1 : 2.0 : 3.7**	**1 : 2.3 : 3.6**	**1 : 2.6 : 3.5**
	8 "10	1 : 1.0 : 2.6	1 : 1.1 : 2.7	1 : 1.3 : 2.6	1 : 1.5 : 2.7	1 : 1.7 : 2.6
¾ to 3 in.......	½ to 1	1 : 2.5 : 6.0	1 : 2.9 : 5.9	1 : 3.2 : 5.9	1 : 3.6 : 5.8	1 : 4.1 : 5.6
	3 " 4	1 : 2.1 : 5.1	1 : 2.4 : 5.2	1 : 2.7 : 5.2	1 : 3.1 : 5.1	1 : 3.5 : 4.9
	6 " 7	**1 : 1.5 : 4.1**	**1 : 1.7 : 4.2**	**1 : 2.0 : 4.2**	**1 : 2.3 : 4.2**	**1 : 2.5 : 4.0**
	8 "10	1 : 1.0 : 2.9	1 : 1.1 : 3.0	1 : 1.3 : 3.0	1 : 1.5 : 3.0	1 : 1.7 : 3.0

PROPORTIONS FOR 2500 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None	½ to 1	1 : 1.8	1 : 2.1	1 : 2.4	1 : 2.9	1 : 3.3
	3 " 4	1 : 1.5	1 : 1.8	1 : 2.1	1 : 2.4	1 : 2.8
	6 " 7	**1 : 1.1**	**1 : 1.3**	**1 : 1.6**	**1 : 1.8**	**1 : 2.1**
	8 " 10	1 : 0.7	1 : 0.8	1 : 0.9	1 : 1.1	1 : 1.3
No. 4 to ¾ in.	½ to 1	1 : 1.6 : 3.2	1 : 1.8 : 3.1	1 : 2.1 : 3.0	1 : 2.4 : 2.7	1 : 2.9 : 2.4
	3 " 4	1 : 1.3 : 2.8	1 : 1.5 : 2.7	1 : 1.7 : 2.6	1 : 2.0 : 2.4	1 : 2.4 : 2.2
	6 " 7	**1 : 1.0 : 2.2**	**1 : 1.1 : 2.2**	**1 : 1.3 : 2.1**	**1 : 1.5 : 2.0**	**1 : 1.8 : 1.8**
	8 " 10	1 : 0.5 : 1.4	1 : 0.6 : 1.4	1 : 0.7 : 1.4	1 : 0.8 : 1.4	1 : 1.0 : 1.3
No. 4 to 1 in.	½ to 1	1 : 1.5 : 3.7	1 : 1.7 : 3.7	1 : 2.0 : 3.5	1 : 2.2 : 3.4	1 : 2.7 : 3.1
	3 " 4	1 : 1.2 : 3.3	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.9 : 3.0	1 : 2.2 : 2.7
	6 " 7	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.5**	**1 : 1.1 : 2.5**	**1 : 1.3 : 2.4**	**1 : 1.6 : 2.3**
	8 " 10	1 : 0.5 : 1.7	1 : 0.6 : 1.7	1 : 0.6 : 1.7	1 : 0.7 : 1.6	1 : 0.9 : 1.5
No. 4 to 1½ in.	½ to 1	1 : 1.4 : 4.2	1 : 1.6 : 4.1	1 : 1.9 : 4.1	1 : 2.2 : 4.0	1 : 2.5 : 3.8
	3 " 4	1 : 1.2 : 3.7	1 : 1.3 : 3.6	1 : 1.5 : 3.6	1 : 1.8 : 3.5	1 : 2.1 : 3.3
	6 " 7	**1 : 0.9 : 2.9**	**1 : 0.9 : 2.8**	**1 : 1.1 : 2.8**	**1 : 1.3 : 2.8**	**1 : 1.5 : 2.6**
	8 " 10	1 : 0.5 : 1.9	1 : 0.5 : 1.9	1 : 0.6 : 1.9	1 : 0.7 : 1.8	1 : 0.8 : 1.8
No. 4 to 2 in.	½ to 1	1 : 1.3 : 4.9	1 : 1.4 : 4.8	1 : 1.6 : 4.9	1 : 1.9 : 4.8	1 : 2.2 : 4.7
	3 " 4	1 : 1.1 : 4.3	1 : 1.2 : 4.2	1 : 1.3 : 4.3	1 : 1.6 : 4.2	1 : 1.8 : 4.1
	6 " 7	**1 : 0.7 : 3.3**	**1 : 0.8 : 3.3**	**1 : 0.9 : 3.4**	**1 1.1 : 3.3**	**1 : 1.2 : 3.3**
	8 " 10	1 : 0.4 : 2.2	1 : 2.4 : 2.2	1 : 0.5 : 2.2	1 : 0.6 : 2.2	1 : 0.6 : 2.2
⅜ to 1 in.	½ to 1	1 : 1.8 : 3.7	1 : 2.0 : 3.6	1 : 2.3 : 3.5	1 : 2.6 : 3.3	1 : 3.0 : 2.9
	3 " 4	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.9 : 2.9	1 : 2.2 : 2.9	1 : 2.5 : 2.6
	6 " 7	**1 : 1.0 : 2.5**	**1 : 1.2 : 2.5**	**1 : 1.3 : 2.4**	**1 : 1.6 : 2.3**	**1 : 1.8 : 2.2**
	8 " 10	1 : 0.6 : 1.6	1 : 0.7 : 1.6	1 : 0.8 : 1.6	1 : 0.9 : 1.6	1 : 1.0 : 1.5
⅜ to 1½ in.	½ to 1	1 : 1.7 : 4.1	1 : 1.9 : 4.1	1 : 2.2 : 4.0	1 : 2.5 : 3.9	1 : 2.9 : 3.6
	3 " 4	1 : 1.5 : 3.6	1 : 1.6 : 3.6	1 : 1.8 : 3.5	1 : 2.1 : 3.4	1 : 2.3 : 3.2
	6 " 7	**1 : 1.0 : 2.9**	**1 : 1.2 : 2.8**	**1 : 1.3 : 2.8**	**1 : 1.5 : 2.7**	**1 : 1.8 : 2.6**
	8 " 10	1 : 0.6 : 1.9	1 : 0.6 : 1.9	1 : 0.8 : 1.8	1 : 0.9 : 1.8	1 : 1.0 : 1.8
⅜ to 2 in.	½ to 1	1 : 1.7 : 4.7	1 : 1.8 : 4.7	1 : 2.1 : 4.7	1 : 2.4 : 4.6	1 : 2.7 : 4.4
	3 " 4	1 : 1.4 : 4.1	1 : 1.5 : 4.1	1 : 1.7 : 4.1	1 : 2.0 : 4.0	1 : 2.3 : 3.9
	6 " 7	**1 : 1.0 : 3.2**	**1 : 1.1 : 3.2**	**1 : 1.2 : 3.2**	**1 : 1.4 : 3.2**	**1 : 1.6 : 3.1**
	8 " 10	1 : 0.5 : 2.1	1 : 0.6 : 2.1	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 0.9 : 2.1
¾ to 1½ in.	½ to 1	1 : 2.0 : 3.8	1 : 2.3 : 3.8	1 : 2.6 : 3.7	1 : 3.0 : 3.6	1 : 3.4 : 3.3
	3 " 4	1 : 1.7 : 3.3	1 : 2.0 : 3.3	1 : 2.2 : 3.2	1 : 2.5 : 3.2	1 : 2.9 : 2.9
	6 " 7	**1 : 1.2 : 2.6**	**1 : 1.4 : 2.6**	**1 : 1.6 : 2.6**	**1 : 1.9 : 2.5**	**1 : 2.1 : 2.3**
	8 " 10	1 : 0.7 : 1.7	1 : 0.8 : 1.7	1 : 0.9 : 1.7	1 : 1.1 : 1.7	1 : 1.2 : 1.6
¾ to 2 in.	½ to 1	1 : 2.0 : 4.4	1 : 2.2 : 4.4	1 : 2.5 : 4.3	1 : 2.9 : 4.3	1 : 3.3 : 4.1
	3 " 4	1 : 1.7 : 3.8	1 : 1.9 : 3.8	1 : 2.1 : 3.8	1 : 2.5 : 3.7	1 : 2.8 : 3.6
	6 " 7	**1 : 1.2 : 3.0**	**1 : 1.4 : 3.0**	**1 : 1.5 : 3.0**	**1 : 1.8 : 3.0**	**1 : 2.0 : 2.8**
	8 " 10	1 : 0.7 : 2.0	1 : 0.8 : 2.0	1 : 0.9 : 2.0	1 : 1.0 : 2.0	1 : 1.2 : 2.0
¾ to 3 in.	½ to 1	1 : 2.0 : 5.0	1 : 2.2 : 5.0	1 : 2.5 : 5.0	1 : 2.7 : 5.0	1 : 3.2 : 4.7
	3 " 4	1 : 1.7 : 4.3	1 : 1.9 : 4.3	1 : 2.1 : 4.3	1 : 2.4 : 4.3	1 : 2.7 : 4.1
	6 " 7	**1 : 1.2 : 3.3**	**1 : 1.4 : 3.4**	**1 : 1.5 : 3.4**	**1 : 1.8 : 3.4**	**1 : 2.0 : 3.3**
	8 " 10	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 0.9 : 2.2	1 : 1.0 : 2.3	1 : 1.2 : 2.3

PROPORTIONS FOR 3000 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – $\frac{3}{8}$ in.
None	½ to 1	1 : 1.5	1 : 1.7	1 : 2.0	1 : 2.3	1 : 2.7
	3 " 4	1 : 1.2	1 : 1.4	1 : 1.7	1 : 1.9	1 : 2.3
	6 " 7	**1 : 0.9**	**1 : 1.0**	**1 : 1.2**	**1 : 1.4**	**1 : 1.6**
	8 " 10	1 : 0.5	1 : 0.6	1 : 0.7	1 : 0.8	1 : 0.9
No. 4 to ¾ in.	½ to 1	1 : 1.3 : 2.7	1 : 1.5 : 2.6	1 : 1.7 : 2.5	1 : 1.9 : 2.4	1 : 2.3 : 2.1
	3 " 4	1 : 1.0 : 2.3	1 : 1.2 : 2.2	1 : 1.4 : 2.2	1 : 1.6 : 2.0	1 : 1.9 : 1.8
	6 " 7	**1 : 0.7 : 1.7**	**1 : 0.8 : 1.7**	**1 : 0.9 : 1.7**	**1 : 1.1 : 1.6**	**1 : 1.3 : 1.4**
	8 " 10	1 : 0.3 : 1.0	1 : 0.4 : 1.0	1 : 0.5 : 1.0	1 : 0.5 : 1.0	1 : 0.6 : 0.9
No. 4 to 1 in.	½ to 1	1 : 1.2 : 3.1	1 : 1.3 : 3.1	1 : 1.5 : 3.0	1 : 1.8 : 2.9	1 : 2.1 : 2.7
	3 " 4	1 : 0.9 : 2.7	1 : 1.1 : 2.6	1 : 1.2 : 2.6	1 : 1.4 : 2.5	1 : 1.7 : 2.3
	6 " 7	**1 : 0.6 : 2.0**	**1 : 0.7 : 2.0**	**1 : 0.8 : 2.0**	**1 : 0.9 : 1.9**	**1 : 1.1 : 1.8**
	8 " 10	1 : 0.3 : 1.2	1 : 0.3 : 1.2	1 : 0.4 : 1.2	1 : 0.5 : 1.2	1 : 0.6 : 1.2
No. 4 to 1½ in.	½ to 1	1 : 1.1 : 3.6	1 : 1.2 : 3.5	1 : 1.5 : 3.5	1 : 1.7 : 3.4	1 : 2.0 : 3.2
	3 " 4	1 : 0.9 : 3.0	1 : 1.0 : 2.9	1 : 1.2 : 2.9	1 : 1.4 : 2.9	1 : 1.6 : 2.7
	6 " 7	**1 : 0.6 : 2.2**	**1 : 0.7 : 2.2**	**1 : 0.8 : 2.2**	**1 : 0.9 : 2.2**	**1 : 1.1 : 2.1**
	8 " 10	1 : 0.3 : 1.4	1 : 0.3 : 1.3	1 : 0.4 : 1.4	1 : 0.5 : 1.4	1 : 0.5 : 1.3
No. 4 to 2 in.	½ to 1	1 : 1.0 : 4.1	1 : 1.1 : 4 1	1 : 1.2 : 4.1	1 : 1.4 : 4.1	1 : 1.6 : 4.0
	3 " 4	1 : 0.8 : 3.4	1 : 0.9 : 3.4	1 : 1.0 : 3.5	1 : 1.1 : 3.4	1 : 1.3 : 3.4
	6 " 7	**1 : 0.5 : 2.6**	**1 : 0.6 : 2.6**	**1 : 0.6 : 2.7**	**1 : 0.7 : 2.6**	**1 : 0.9 : 2.6**
	8 " 10	1 : 0.2 : 1.6	1 : 0.3 : 1.6	1 : 0.3 : 1.7	1 : 0.4 : 1.7	1 : 0.4 : 1.7
$\frac{3}{8}$ to 1 in.	½ to 1	1 : 1.4 : 3.1	1 : 1.5 : 3.0	1 : 1.8 : 2.9	1 : 2.1 : 2.8	1 : 2.4 : 2.6
	3 " 4	1 : 1.1 : 2.6	1 : 1.3 : 2.6	1 : 1.5 : 2.5	1 : 1.7 : 2.4	1 : 2.0 : 2.2
	6 " 7	**1 : 0.8 : 2.0**	**1 : 0.8 : 2.0**	**1 : 1.0 : 1.9**	**1 : 1.1 : 1.9**	**1 : 1.3 : 1.8**
	8 " 10	1 : 0.4 : 1.2	1 : 0.4 : 1.2	1 : 0.5 : 1.2	1 : 0.6 : 1.2	1 : 0.7 : 1.1
$\frac{3}{8}$ to 1½ in.	½ to 1	1 : 1.4 : 3.5	1 : 1.5 : 3.4	1 : 1.7 : 3.4	1 : 2.0 : 3.3	1 : 2.3 : 3.1
	3 " 4	1 : 1.1 : 3.0	1 : 1.2 : 2.9	1 : 1.4 : 2.9	1 : 1.6 : 2.8	1 : 1.9 : 2.6
	6 " 7	**1 : 0.6 : 2.2**	**1 : 0.8 : 2.2**	**1 : 1.0 : 2.2**	**1 : 1.1 : 2.1**	**1 : 1.3 : 2.0**
	8 " 10	1 : 0.4 : 1.4	1 : 0.4 : 1.4	1 : 0.5 : 1.4	1 : 0.6 : 1.3	1 : 0.7 : 1.3
$\frac{3}{8}$ to 2 in.	½ to 1	1 : 1.3 : 4.0	1 : 1.4 : 4.0	1 : 1.6 : 4.0	1 : 1.9 : 3.9	1 : 2.1 : 3.8
	3 " 4	1 : 1.0 : 3.4	1 : 1.2 : 3.4	1 : 1.3 : 3.3	1 : 1.5 : 3.3	1 : 1.7 : 3.2
	6 " 7	**1 : 0.7 : 2.6**	**1 : 0.8 : 2.5**	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.6**	**1 : 1.1 : 2.5**
	8 " 10	1 : 0.4 : 1.6	1 : 0.4 : 1.6	1 : 0.5 : 1.6	1 : 0.5 : 1.6	1 : 0.6 : 1.6
¾ to 1½ in.	½ to 1	1 : 1.6 : 3.2	1 : 1.8 : 3.2	1 : 2.1 : 3.2	1 : 2.4 : 3.1	1 : 2.7 : 2.9
	3 " 4	1 : 1.3 : 2.7	1 : 1.5 : 2.7	1 : 1.7 : 2.7	1 : 2.0 : 2.6	1 : 2.3 : 2.5
	6 " 7	**1 : 0.9 : 2.0**	**1 : 1.0 : 2.1**	**1 : 1.2 : 2.0**	**1 : 1.4 : 2.0**	**1 : 1.5 : 1.8**
	8 " 10	1 : 0.5 : 1.2	1 : 0.5 : 1.3	1 : 0.6 : 1.3	1 : 0.7 : 1.3	1 : 0.8 : 1.2
¾ to 2 in.	½ to 1	1 : 1.6 : 3.7	1 : 1.8 : 3.7	1 : 2.0 : 3.7	1 : 2.4 : 3.6	1 : 2.6 : 3.5
	3 " 4	1 : 1.3 : 3.1	1 : 1.5 : 3.1	1 : 1.6 : 3.1	1 : 1.9 : 3.1	1 : 2.2 : 3.0
	6 " 7	**1 : 0.9 : 2.4**	**1 : 1.1 : 2.4**	**1 : 1.1 : 2.4**	**1 : 1.3 : 2.4**	**1 : 1.5 : 2.3**
	8 " 10	1 : 0.5 : 1.5	1 : 0.5 : 1.5	1 : 0.6 : 1.5	1 : 0.7 : 1.5	1 : 0.8 : 1.5
¾ to 3 in.	½ to 1	1 : 1.6 : 4.2	1 : 1.8 : 4.2	1 : 2.0 : 4.2	1 : 2.3 : 4.1	1 : 2.6 : 4.0
	3 " 4	1 : 1.3 : 3.5	1 : 1.5 : 3.6	1 : 1.6 : 3.6	1 : 1.9 : 3.6	1 : 2.1 : 3.5
	6 " 7	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.6**	**1 : 1.1 : 2.6**	**1 : 1.3 : 2.6**	**1 : 1.4 : 2.6**
	8 " 10	1 : 0.5 : 1.6	1 : 0.5 : 1.6	1 : 0.6 : 1.7	1 : 0.7 : 1.7	1 : 0.8 : 1.7

APPENDIX 17.

EFFECT OF OILS AND MISCELLANEOUS LIQUIDS ON CONCRETE AND METHOD OF PROTECTIVE TREATMENT WHERE REQUIRED

Liquid	Effect on Untreated Concrete	Surface Treatment
MINERAL OILS[1]		
30° Baumé or heavier....	Good concrete unaffected. Very slight surface penetration.	None—Good concrete well spaded or cement mortar finish sufficient.
Fuel Oils above 30° Baumé. Distillates. Gas and Lubricating Oils.[2]...............	Good concrete unaffected. More penetration than for heavy oils.	Coatings of the magnesium fluosilicate class, glues or varnishes required for storage tanks.
Kerosene, Gasoline, Benzine.............	Good concrete unaffected. Considerable penetration.	Gasoline-proof coatings producing glazed surface or treatment with iron compounds.
ANIMAL OILS (SOLID FATS)[3]		
Lard and Lard Oil.......	May attack concrete slowly, particularly if in melted condition.	Various proprietary compounds recommended by manufacturers of technical paints.
Goose Fat, Beef Marrow, Beef and Mutton Tallow and Tallow Oil	No definite information. Probably similar to lard oil.	Probably similar to that for lard oil.
ANIMAL OILS (LIQUID FATS)		
Marine:		
Menhaden Oil.........	No effect on good concrete.	Cushman's tests indicate various coatings no better than plain concrete.
Cod Liver Oil. ...... Shark Liver Oil. .... Seal and Whale Oil..	More or less disintegration depending on quality of concrete.	Various proprietary compounds recommended by manufacturers of technical paints.
Terrestrial:		
Sheep's foot...........	"	"
Horse's foot...........	"	"
Neat's foot[4]...........	No effect on good concrete.	No treatment required.

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[1] Signal oil, used by railroads, is a mixture of animal fat with mineral oil. Probably has about the same effect on concrete as lard oils.

[2] Some lubricating oils are mixtures of mineral and animal oils.

[3] Bureau of Standards' tests with concrete tanks show slight roughening of surface at end of 12 months and considerable deposit on surface through saponification.

[4] Bureau of Standards noted slight deposit due to saponification at end of 12 months.

APPENDIX 17—*Continued.*

Liquid	Effect on Untreated Concrete	Surface Treatment
VEGETABLE OILS (SOLID FATS)		
Cocoanut Oil.[1]	Some action if stored in closed tank. Progressive disintegration if in contact with surfaces exposed to air.	Several proprietary compounds seem to have proved effective on floors. Sodium silicate or magnesium fluosilicate treatment apparently sufficient for closed tanks.
Palm Oil	No information.	No information.
VEGETABLE OILS		
Drying:		
Hemp Oil. Poppyseed Oil. Tobacco Oil.	No information.	No information.
Linseed Oil.[2] Rosin Oil. Turpentine	No effect on good concrete. Considerable penetration of turpentine.	Cushman's tests indicate various coatings no better than plain concrete for linseed and rosin oils.
Semi-Drying:		
Cottonseed Oil.	No action if stored in closed tank of good concrete.	Same as for cocoanut oil.
Rape Seed Oil. Castor Oil. Mustard Oil.	Progressive disintegration if in contact with surfaces exposed to air.	
Non-Drying:		
Olive Oil.	Probably some action.	Cushman's tests show proprietary coatings of varnish type effective.
Butter Oil.(?)		

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[1] Bureau of Standards' tests with concrete tanks show considerable softening and roughening of surface at end of 12 months.

[2] Bureau of Standards noted at end of 12 months considerable deposit on surfaces of concrete tanks containing both boiled and raw linseed oil, due to saponification, but concrete showed no deterioration.

APPENDIX 17—*Continued.*

Liquid	Effect on Untreated Concrete	Surface Treatment
	MISCELLANEOUS LIQUIDS	
Tanning Liquors........	Acid liquors show considerable effect. Other tanning extracts have no action.	Bituminous acid-proof paints effective for tanks holding acid tanning solutions. Good concrete with or without mortar finish sufficient for other tanning liquors.
Sulfite Liquor...........	Attacks untreated concrete tanks.	Cushman's tests indicate bituminous acid-proof paints effective. Paraffin coating fair.
Cider Vinegar...........	Acetic acid attacks concrete.	Cushman's tests indicate bituminous acid-proof paints effective. Paraffin coatings applied hot also useful for tanks.
Sauerkraut Brine........	No action on good concrete.	Cushman's tests show special treatments no better than untreated concrete.
Whey..................	More or less action depending on quality of concrete.	Cushman's tests show proprietary coating of varnish type effective. Sodium silicate treatment used on storage tanks.
Buttermilk..............	No action on good concrete.	Untreated tanks used successfully to store buttermilk.
Molasses...............	No action in closed concrete.	Good concrete well spaded or finished with cement mortar sufficient. Annapolis mixture sometimes used.
Sulfuric Acid Solutions...	Progressive disintegration, particularly where concrete is subject to abrasion.	Bituminous acid-proof paints or mastic coating effective.

APPENDIX 18.

SUPERVISION AND INSPECTION OF CONCRETE CONSTRUCTION.

1. All work shall be under the supervision of the Engineer, under whose direction the work is to be conducted in accordance with the provisions of the specifications; the Engineer shall interpret the meaning and intent of the drawings and specifications, and pass upon the material and workmanship, and his acceptance shall be a condition precedent to payment. In case of disputes, or of unforeseen conditions the decision of the Engineer as to quantities, quality and acceptability of the work shall be binding.

2. Line and grade will be given by the Engineer as provided under the contract. The Contractor shall inform the Engineer a reasonable time in advance so that lines and grades may be conveniently and accurately placed. Such points or marks as may be given by the Engineer shall be carefully preserved by the Contractor.

3. The Inspector as a representative of the Engineer shall be in immediate charge of the inspection of material and of placing material in the finished work. The Contractor shall at all times give to the Owner, the Engineer or Inspector, entrance to the work and to the place of manufacture of any materials entering into the work, and facilities for inspecting the work or materials, both at completion and in process of manufacture and construction. The manufacturer shall furnish the Engineer such chemical and physical records of the materials as may be required under the contract and any other records pertaining to the quality of the material that the manufacturer may possess shall be available for the information of the Engineer or Inspector.

4. The Inspector shall be present before starting any unit of field work and during the process of construction of any unit of the structure, to see that the work is done according to the provisions of the specifications, as interpreted by the Engineer.

5. The tests required under these specifications will be made by the Engineer and unless otherwise specifically provided for will be carried out at the expense of the Owner. The Contractor shall afford every opportunity for the proper conduct of the tests and he shall further provide such facilities for obtaining, handling, storing, and

testing specimens and samples as the Engineer may require. For such work the Contractor shall receive compensation for actual expense for labor and materials.

6. The inspection of the work shall not relieve the Contractor of his obligations under the contract. Defective work shall be made good and unsuitable materials rejected, even though such work and materials have previously been accepted.

REPORT OF COMMITTEE C-3
ON
BRICK

The Conference on Elimination of Unnecessary Sizes and Type of Paving Brick, organized by the U. S. Department of Commerce has recommended the elimination of one more size, leaving the following five as the recognized sizes and types of paving brick:

	Width, in.	Depth, in.	Length, in.
Plain wire-cut brick (vertical fiber, lugless)....	3[a]	4[a]	8½
Plain wire-cut brick (vertical fiber, lugless)....	3½[a]	4[a]	8½
Repressed lug brick..........................	3½	4	8½
Wire-cut lug brick (Dunn)....................	3½	3	8½
" " " "	3½	4	8½

[a] These bricks are customarily laid in the pavement to give a depth of 3 in. and 3 ½ in., respectively, by 4 in. in width and 8 ½ in. in length.

Committee C-3 recommends that this action of the Conference be approved by the Society, and that the five recognized sizes mentioned above be published as an appendix to the Standard Specifications for Paving Brick (C 7 – 15),[1] superseding the recommendation made by the committee in 1923.[2]

A similar Conference on standard sizes for building brick has resulted in the promulgation by the Department of Commerce of Simplified Practice Recommendation No. 7. Inasmuch as the size recommended in this document is the same as that now called for in our Standard Specifications for Building Brick (C 21 – 20), Committee C-3 recommends that the above recommendation be approved by the Society.

The attached specifications[3] for concrete building brick are recommended for adoption as tentative. The letter ballot on this question resulted as follows: Affirmative, 14; negative, 5; not voting, 4.

An organization has been perfected whereby it is hoped to obtain, correlate, and record information about the present condition of bricks in old buildings.

The new specifications for concrete brick include a method for measuring compressive strength, which is different from the method called for in the present Specifications for Building Brick (C 21 – 20).

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[1] 1921 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 194 (1923).

[3] See p. 813.—Ed.

A study of this and similar questions is being actively pursued by a newly organized sub-committee on testing methods.

Considerable discussion has been had about the expansion of the committee to provide for larger representation of manufacturers and users of bricks made of materials other than clay. No action is recommended at present.

The committee accepts the definitions of the terms "clay," "surface clay," "fire clay," and "shale," as suggested by Committee E-8 on Nomenclature and Definitions. The committee accordingly recommends that the definitions of the terms "surface clay," "fire clay" and "shale," appearing in the Standard Specifications for Sewer Brick (C 32 - 23),[1] be revised to read as follows:

> "*Surface Clay.*"—An unconsolidated, unstratified clay, occurring on the surface.
>
> "*Fire Clay.*"—A sedimentary clay of low flux content.
>
> NOTE.—It is usually associated with coal measures.
>
> "*Shale.*"—A thinly stratified, consolidated sedimentary clay with well-marked cleavage paralled to the bedding.

This report has been submitted to letter ballot of the committee, which consists of 23 members, of whom 20 have voted affirmatively, none negatively, and 3 have refrained from voting.

Respectfully submitted on behalf of the committee,

T. R. LAWSON,
Chairman.

W. E. EMLEY,
Secretary.

EDITORIAL NOTE

The recommendation of the committee that the recognized sizes and types of paving brick, recommended by the Conference on Elimination of Unnecessary Sizes and Types of Paving Brick, be approved by the Society and that these recommended sizes appear as an appendix to the Standard Specifications for Paving Brick was approved at the annual meeting. The proposed revisions of the Standard Specifications for Clay Sewer Brick were approved at the annual meeting as recommended in this report, and were subsequetly adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed Tentative Specifications for Concrete Building Brick, referred to in this report, were accepted for publication as tentative and appear on page 813.

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[1] A.S.T.M. Standard Adopted in 1923.

REPORT OF COMMITTEE C-4

ON

CLAY AND CEMENT-CONCRETE SEWER PIPE

Committee C-4 on Clay and Cement-Concrete Sewer Pipe has held two meetings, both well attended, since the last annual report was presented.

On May 30, 1923, the committee suffered irreparable loss in the death of its chairman, Dr. Rudolph Hering. An acknowledgment of the important services rendered by Doctor Hering as chairman during a period of eighteen years, in the form of a resolution, was adopted at the meeting of June 28, 1923. This resolution was also adopted by the Society.[1]

At the meeting of June 28, 1923, A. J. Provost, Jr., was elected chairman, G. T. Hammond, vice-chairman, and F. B. Lysle, secretary, to fill the respective unexpired terms of office. An Advisory Committee has been created. Its members consist of the officers of the committee and the chairmen of the five sub-committees.

A list of sewer pipe specials, for standard manufacture, compiled by the Eastern Clay Products Association and the Clay Products Association for consideration by the U. S. Department of Commerce, in connection with the proposed elimination of unnecessary types, was tentatively approved with certain modifications.

Sub-Committee II on Chemical Requirements has recommended amending the Standard Specifications for Cement-Concrete Sewer Pipe by adding a footnote relating to the non-use of this pipe where the sewage shows an acid reaction.

Sub-Committee III on Dimensions and Their Permissible Variations.—This sub-committee recommended the addition of a lighter weight pipe and the formulation of specified conditions under which the standard pipe and the lighter pipe may be properly used. The recommendation was approved in principle and referred back to the sub-committee for further report.

Sub-Committee V on Nomenclature and Definitions.—This sub-committee had under consideration the proposed amended definitions of terms relating to clay, submitted by Committee E-8 on Nomenclature and Definitions, but made no report during the year.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 31 (1923).

Advisory Committee.—This committee presented a unanimous report recommending the reorganization of Committee C-4 with 20 members, instead of 28, for the reason that it has been found impracticable to secure the sustained interest of the proportionally large number of non-producer members. The report was approved and ordered submitted to letter ballot. Subsequent conference with the Executive Committee of the Society indicated that some modification of the plan would be required. The submission of the matter to letter ballot was therefore postponed until further action is possible.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

It is recommended that the revisions of the Standard Specifications for Clay Sewer Pipe (C 13 – 20) accepted for publication as tentative in 1923[1] be adopted as standard and that the Standard Specifications be revised accordingly when the Book of Standards is next issued. The above recommendation was submitted to letter ballot of Committee C-4 with the following result: Affirmative, 20; negative, 3; not voting, 2.

It is recommended that the revisions of the Standard Specifications for Cement-Concrete Sewer Pipe (C 14 – 20) accepted for publication as tentative in 1923[1] be adopted as standard and that the Standard Specifications be revised accordingly when the Book of Standards is next issued. The above recommendation was submitted to letter ballot of Committee C-4 with the following result: Affirmative, 18; negative, 2; not voting, 5.

It is recommended that the following revision of the Standard Specifications for Cement-Concrete Sewer Pipe (C 14 – 20)[2] be accepted for publication as tentative:

Section 1.—Add the following footnote:

> "*Caution.*—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction."

The revision is recommended for the reason that, in the opinion of the committee, acid sewage may adversely affect cement-concrete sewer pipe. This recommendation was approved by Sub-Committee II and ordered submitted to letter ballot of the main committee with the following result: Affirmative, 13; negative, 7; not voting, 5.

The committee recommends the incorporation in the Standard Definitions of Terms Relating to Sewer Pipe (C 8–15)[2] of the definitions of the terms "clay," "surface clay," "fire clay" and "shale" approved by Committee E-8 on Nomenclature and Definitions as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 197 (1923).

[2] 1921 Book of A.S.T.M. Standards.

"*Clay.*—An earthy or stony mineral aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry and vitreous when burned at a sufficiently high temperature.

"*Surface Clay.*—An unconsolidated, unstratified clay, occurring on the surface.

"*Fire Clay.*—A sedimentary clay of low flux content.

NOTE.—It is usually associated with coal measures.

"*Shale.*—A thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding."

The committee further recommends that the definitions for terms "surface clay," "fire clay" and "shale" appearing in the Standard Specifications for Clay Sewer Pipe (C 13 – 20) be revised to conform to the wordings given above.

It is recommended that the Tentative Specifications for Required Safe Crushing Strengths of Sewer Pipe to Carry Loads from Ditch Filling (C 15 – 17 T) be continued as tentative for another year.

This report has been submitted to letter ballot of the committee, which consists of 25 members, of whom 17 have voted affirmatively, 4 negatively, and 4 have refrained from voting.

Respectfully submitted on behalf of the committee,

ANDREW J. PROVOST, JR.,
Chairman.

GEORGE T. HAMMOND,
Vice-Chairman.

F. B. LYSLE,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Clay Sewer Pipe and for Cement-Concrete Sewer Pipe, proposed in 1923, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Definitions of Terms Relating to Sewer Pipe, referred to in this report, were approved and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The definitions, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revision of the Standard Specifications for Cement-Concrete Sewer Pipe was accepted for publication, as recommended in this report, and appears on page 1120.

REPORT OF COMMITTEE C-6
ON
DRAIN TILE

The committee has held only one meeting during the year, that of February 27, in Chicago.

The principal activity of the committee has been the continuation of the research investigation, begun in 1921, on the development of chemical tests and chemical test requirements for drain tile to determine their resistance to the action of alkalies and acids in the soil. Four separate investigations are being carried on by the following agencies: (1) laboratory tests at the Iowa Engineering Experiment Station, under the immediate direction of Mr. W. J. Schlick, Drainage Engineer of the Experiment Station Staff; (2) field tests in South Dakota and Colorado and coordinate laboratory research, by the Structural Materials Research Laboratory of Lewis Institute, with the cooperation of the Portland Cement Association, under the direction of Mr. D. A. Abrams; (3) laboratory and field tests conducted by the U. S. Bureau of Public Roads, in cooperation with the College of Agriculture, University of Minnesota, and the Department of Drainage and Waters, State of Minnesota; and (4) field and laboratory tests conducted by a committee of the Engineering Institute of Canada, and reported by G. M. Williams, secretary of that committee.

Abstracts of the reports of these investigations are given below:

I. IOWA ENGINEERING EXPERIMENT STATION

The principal object of these investigations was the development of a test method for determining the durability of concrete drain tile in alkali soils. During the past year the work, started three years ago and summarized in the 1923 report of Committee C-6[1] (Part I of this report), has been extended by chemical studies to show the nature and extent of the chemical reactions (Part II of this report).

The studies given in Part I have shown that immersion in 15-per-cent solutions of sodium and magnesium sulfate may be used for such a test, but that both solutions must be used, and that the time required is too long to make the test applicable except in determining the general quality of the output of a factory.

The chemical studies given in Part II show that when the salt solution used is in contact with all particles of the cement the reaction with the calcium of the cement is very rapid and complete, and that the changes in the volumes of insoluble compounds are logical explanations of the effects of the various salt solutions as found in field investigations and in the tests of Part I.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 198 (1923).

PART I. STUDIES WITH PIECES FROM BUREAU OF STANDARDS TILE

The principal tests consist of a study of the action of solutions of the various salts common to natural alkalies on pieces from 15 of the 21 series from the reserve stock of the tile prepared by the U. S. Bureau of Standards for their field investigations (started in 1912 and reported in *Technologic Papers Nos. 44 and 95*). The solutions used are 2, 5, 10, and 15-per-cent sodium sulfate, 10 and 15-per-cent magnesium sulfate, 10-per-cent magnesium and sodium chloride, and 15-per-cent sodium carbonate.

The results after periods of 110 to 143 weeks in the immersion tests and after 175 treatments in the combined tests (alternate immersion in a 15-per-cent solution of sodium sulfate, and drying) may be summarized as follows:

1. The results in these tests are in general agreement with those reported by the Bureau of Standards from the field investigations using these tile, and with those reported from other field and laboratory studies of this problem.

2. The actions are most rapid with the sulfates, with the higher concentrations and with magnesium as compared to sodium. The action with the magnesium sulfate was more rapid than with sodium sulfate, except for series 16, 20, and 21, where the reverse is true.

3. The specimens in solutions of sodium chloride and carbonate have shown no action. The specimens in the 10-per-cent magnesium chloride showed no signs of action till 76 weeks, three pieces from series 21 being destroyed in from 76 to 79 weeks; there has been no further sign of action.

4. In nearly all cases the effect produced was apparently the result of physical action which, for specimens continually immersed, must have been due to chemical action.

PART II. CHEMICAL STUDIES

These chemical studies were made by treating 10-g. samples (of a large sample) of ground, cured, neat cement (passing a 200-mesh sieve) with 5-per-cent solutions of sodium and magnesium sulfates and chloride and sodium carbonate, siphoning off the clear liquid at regular intervals and adding new solution. From analyses of the original samples and of the solutions, and weights of the amounts of withdrawn and added solutions, it was possible to determine the action at any time. At the end of each test (after treating with 1600 to 2400 g. of solution in approximately 50-g. increments) the resulting residue was washed, dried, weighed and its specific gravity determined, thus affording a check on the cumulative calculated action. Similar tests were made using chemically free calcium oxide.

The results of these studies may be summarized as follows:

1. The chemical reactions proceed as though calcium hydrate were treated with these solutions.

2. The magnesium salts react with the calcium of the cement very rapidly, 85 to 95 per cent of the calcium being reacted with after treatment with 350 to 400 g. of testing solution. The action of the sodium sulfate and chloride are much slower, 32 and 42 per cent, respectively, being reacted upon after treating with 1600 g. of solution.

3. The weights and volumes of the residues increase rapidly during treatment with the sulfate solutions, and decrease during treatment with the chloride solutions. The calculated volume of the residue after 8 days' treatment with magnesium sulfate was 2.208 times the volume of the original sample. The calculated volume of the residue after 7 days' treatment with magnesium chloride was 0.82 times the volume of the original sample. The calculated volume of the residue after treatment with sodium sulfate at no time exceeded 1.12 times that of the original sample.

4. These records of rate of chemical action and of the volumes of the insoluble compounds formed are a logical explanation of the results found in the studies given in Part I. They show that with magnesium sulfate the chemical action is rapid and the changes in volume of insoluble compounds are such as to produce rapid physical effects; also, that although the chemical action is rapid with magnesium chloride, the changes in volume are such as to produce little physical effect.

II. U. S. BUREAU OF PUBLIC ROADS

In cooperation with the College of Agriculture, University of Minnesota, and the Department of Drainage and Waters, State of Minnesota, the Bureau of Public Roads is continuing the investigations relative to drain tile at University Farm, St. Paul, Minnesota, under the direction of Mr. D. G. Miller, Senior Drainage Engineer.

The research work in this laboratory consists primarily of studies which have for their object the general improvement of the quality of farm drain tile. At the present time, efforts are being directed specifically toward the development of a concrete tile that will endure under soil conditions that heretofore have proved detrimental, the first work dealing with tile for service in soils ordinarily referred to as "alkali."

In connection with this work there have been made to date in the laboratory a total of about 10,000 2 by 4-in. concrete and mortar cylinders, while experimental drain tile have been made at three plants in Minnesota. It is yet too early to report progress on a good many phases of the work undertaken.

A considerable portion of the work of the past year has had to do with the curing of concrete, as it has been found that variation in this factor alone exerts a very great influence on the behavior of specimens subjected to the action of sulfate waters. So far, perhaps one of the most outstanding features of this phase of the work has been the experimental results obtained by steam curing, as in all cases specimens so cured are displaying what seems at this time to be greatly increased resistance to attack. As yet it has not been possible to test under compression steam-cured specimens after long-time storage in sulfate waters, but year-old cylinders in six series have had an average strength slightly above normal as compared with cylinders from the same batches in distilled water. The general appearance, so far, of the steam-cured cylinders in solutions of magnesium and sodium sulfate is all that could be desired, except for a very slight rounding of the edges of some of the cylinders at the end of 90 weeks. Long-time tests of these cylinders should be of considerable value.

By steam curing is meant curing in water vapor at, or near, the normal boiling temperature of 212° F. (100° C.) for water which differs greatly from the curing at commercial tile plants where the temperature of the curing rooms rarely exceeds 100° F. (38° C.).

The field work for the current fiscal year consisted in part of making up and installing 1500 6-in. experimental drain tile. These were placed last fall at five different points, representing field test conditions as follows:

1. Minnesota Agricultural College, University Farm—neutral mineral soil;
2. Broughton Farm, Lyon County, Minnesota—alkali soil, sulfate type;
3. Peat Experimental Farm, Anoka County, Minnesota—raw peat soil;
4. Fred Bleesey Slough, Cass County, North Dakota—alkali soil (sulfates and chlorides);
5. Medicine Lake, Pennington County, South Dakota—sulfate water, about 4 per cent.

In addition to installing the drain tile in Medicine Lake, 2000 cylinders are being put in the same lake. This water represents almost ideal sulfate conditions for field tests of this kind, as about 63 and 26 per cent of the total salts are, respectively, magnesium and sodium sulfate.

III. ENGINEERING INSTITUTE OF CANADA

(NOTE.—The following abstract is taken from the report of the committee of the Engineering Institute which was recently presented at the annual meeting of the Institute.)

No extensive field work has been undertaken since the original installation of test specimens in the fall of 1921. Additional specimens have been made and installed from time to time as new compounds and treatments, which might have merit in prolonging the life of concrete, have been brought to the attention of members of the committee. Specimens containing each material have been installed at each of the three exposure sites, Cassils, Alberta, Grandora, Saskatchewan, and Deacon, Manitoba.

Yearly inspections have been made of the condition of the blocks at each site and samples of the alkaline ground water to which the specimens are exposed have been secured for analysis. While some cases of partial and complete disintegration have occurred, it is yet too early to attempt to draw definite conclusions as to the relative durability of the different concretes. In general, those concretes in which various integral water-proofing compounds and so-called alkali-proof compounds have been employed have failed to show that there is any advantage to be gained by using them; in fact, most specimens so treated show less resistance to the action of the salts in the ground water than similar blocks that have not been treated.

Cooperation with the field experiments on blocks has been continued, analyses being made from time to time of the ground water from the experimental plots as well as some of the waterproofing and integral compounds used in the field work.

The work on the action of sulfate solutions on portland cement, as mentioned in the last report, where intimate contact was effected by shaking the powdered cement with various solutions has been discontinued for the present as the interpretation of the results obtained must depend largely on work with the individual substances present in cement. Further, satisfactory methods for analyzing the solid phase after decomposition so as to determine the quantity of such chemical substance present were not obtained. The work done on the effect of hydrogen ion concentration on disintegration of cement has given some interesting results, and this method is being used in all the series of experiments where applicable. When large enough samples of the silicates and aluminates contained in cement are obtained, we intend to carry on further work on endosmosis with membranes of these substances in the pure state with the hope of getting at the fundamental factors in the effect of alkalinity on the deterioration of concrete.

The work on the effect of salt solutions on the concentration and expansion of mortars is still being continued and promises to supply a method of connecting up the microscopic work with the results on briquettes and bars.

The experiments on the pure constituents of portland cement are well started. Small quantities of the three compounds, tricalcium aluminate ($3CaO \cdot Al_2O_3$), tricalcium silicate ($3CaO \cdot SiO_2$), and dicalcium silicate ($2CaO \cdot SiO_2$), have been prepared using very pure raw materials. These raw materials were white marble, containing 98.8 per cent of $CaCO_3$, as the source of calcium; commercial flint, containing 99.5 per cent of SiO_2, as the source of silica; and pure alumina made in the laboratory from alum as the source of Al_2O_3.

The preparation of the three above-mentioned compounds involved from eight to ten heat treatments of the mix, the furnace being held at the proper temperature for a period of three or four hours. The resulting clinker was withdrawn and suddenly cooled and then finely ground. This process was continued until microscopic examination showed that the product was entirely homogeneous, special tests being made to insure the absence of free lime.

First, a series of tests was made with the three constituents of cement and solutions of sodium sulfate and magnesium sulfate. All the compounds were attacked and decomposed, but the time required for the decomposition varied, being greatest with the dicalcium silicate. Samples of each of the compounds were hydrated and two series of tests made with each of the hydrated constituents. One series was made with solutions of varying concentration of sodium sulfate, and one with solutions of magnesium sulfate of similar strengths. All of these hydrated compounds were decomposed by the sulfate solutions, the progress of the decomposition being observed with the petrographic microscope and a record kept of the changes by means of photomicrographs. These tests are not yet complete.

The aluminates present in the French high-alumina cements are also being prepared and these will be studied in the same way.

Committee C-6 recommends the following revisions of the Standard Specifications for Drain Tile (C 4 – 21).[1]

Section 4.—Change the second, third, and fourth paragraphs from their present form: namely,

"(*b*) By *shale* is meant a stratified clay, usually red-burning, more or less indurated by heat or pressure, with well-marked cleavage, laid down prior to the present geological epoch.

"(*c*) By *fire clay* is meant a stratified clay, usually buff-burning, usually less indurated than shales, with poorly marked cleavage, laid down prior to the present geological epoch.

"(*d*) By *surface clay* is meant an unstratified, unconsolidated plastic glacial or alluvial clay, laid down by the glacial ice sheet, or on the flood plains of rivers, during the present geological epoch."

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[1] **1921 Book of A.S.T.M. Standards.**

to read as follows:

"(*b*) *Shale* is a thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.[1]

"(*c*) *Fire clay* is a sedimentary clay of low flux content.[1]

NOTE.—It is usually associated with coal measures.

"(*d*) *Surface clay* is an unconsolidated, unstratified clay, occurring on the surface." [1]

Table I.—Insert immediately under the title the following cautionary note:

"CAUTION.—Drain tile meeting these requirements are not necessarily safe against cracking in ditches. For safe requirements as against cracking see Table II."

Add a footnote reference to the number "42" in the first column to read as follows:

"Larger sizes recommended as standard are as follows: 45, 48, 54, and 60 in."

Committee C-6 recommends that these revisions, together with the revisions appearing in the report of Committee C-6 for 1923,[2] be referred to letter ballot of the Society for adoption as standard.

Committee C-6 submits the following definition of the term "drain tile" as information:

"*Drain Tile.*—Pipe suitable for drains to remove ground water or surface water. They may be of any suitable material or design."

This report has been submitted to letter ballot of the committee, which consists of 16 members, of whom 14 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

G. W. PICKELS,
Secretary.

ANSON MARSTON,
Chairman.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Drain Tile, submitted in 1923, and amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

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[1] Definition as adopted by Committee E-8 on Nomenclature and Definitions.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 205 (1923).

REPORT OF COMMITTEE C-7
ON
LIME

Committee C-7 has held two regular meetings since the last annual meeting of the Society. At the March meeting, revised By-Laws to govern the committee were submitted and were ordered sent to letter ballot. By consent of the committee and ruling of the Chair, the committee functioned at the March meeting as though these By-Laws were already in effect. They have since been accepted by Committee C-7, the vote being: affirmative 29, opposed none, not voting none, not heard from 8. Under these By-Laws an Advisory Committee, consisting of the officers of Committee C-7 and the chairmen of the permanent sub-committees, replaces Sub-Committee I on Coordination. In order to facilitate the transaction of committee business, the Advisory Committee is given power to act for Committee C-7 in the interim between stated meetings of the committee.

For convenience, the various activities of Committee C-7 are grouped in the order of the respective sub-committees.

Sub-Committee II on Lime for Structural Purposes.—This sub-committee has studied the method for determining the percentage of residue in quicklime for structural purposes. The research work conducted developed the necessity for certain changes in the method as described in the Tentative Specifications for Quicklime for Structural Purposes (C 5 – 22 T).[1] These changes are included in the revised tentative specifications appended hereto.[2]

With slight changes elaborating on the description of the method for determining plasticity, the Tentative Specifications for Hydrated Lime for Structural Purposes (C 6 – 23 T)[3] have been submitted to Committee C-7 with the recommendation that they be advanced to standard.

Test data are being collected preparatory to the preparation of specifications for lime block.

Sub-Committee III on Lime for the Chemical Industries.—Through the functioning of the Coordinating Committee referred to in the

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 688 (1922).

[2] See p. 802.—Ed.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 620 (1923).

1923 Annual Report of Committee C-7, the following actions relative to particular specifications have been taken:

The Tentative Specifications for Quicklime and Hydrated Lime for Use in the Textile Industry (C 48 – 22 T)[1] have been submitted to Committee C-7 with the recommendation that they be advanced to standard.

The Tentative Specifications for Quicklime and Hydrated Lime for the Manufacture of Silica Brick (C 49 – 22 T)[2] have been accepted by the Interdepartmental Conference (see U. S. Bureau of Standards *Circular No. 153*). These specifications have been submitted by Sub-Committee III to Committee C-7, with the recommendation that they be advanced to standard.

The Tentative Specifications for Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper (C 45 – 22 T)[3] have been revised and submitted to Committee C-7, with the recommendation that they be continued as tentative.

The revision recommended in these specifications is as follows:

Section 2 (b).—Change from its present form: namely,

“(*b*) The quicklime or hydrated lime shall conform to the following requirements as to chemical composition, calculated to the non-volatile basis:

Calcium oxide (CaO), minimum	94 per cent
Magnesium oxide (MgO), maximum	3 “
Iron and aluminum oxides (Fe_2O_3 and Al_2O_3) and insoluble matter, maximum	3 “
Carbon dioxide (CO_2), maximum:	
(*a*) If sample is taken at place of manufacture	
(1) Quicklime	3 “
(2) Hydrated lime	5 “
(*b*) If sample is taken at other than place of manufacture	
(1) Quicklime	5 “
(2) Hydrated lime	7 “ ”

to read as follows:

“(*b*) The standard composition for quicklime shall be a content of 90 per cent of available calcium oxide calculated on the basis of the weight of the sample taken at the point of manufacture.

“(*c*) The standard composition for hydrated lime shall be a content of 85 per cent of available calcium hydroxide calculated on the basis of the weight of the sample taken at the point of manufacture.”

The Tentative Specifications for Quicklime and Hydrated Lime for Use in the Manufacture of Sulfite Pulp (C 46 – 22 T)[4] have been revised and submitted to Committee C-7, with the recommendation that they be continued as tentative. It should be noted that the revised specifications contain requirements for quicklime only.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 703 (1922).

[2] *Ibid.*, p. 705.

[3] *Ibid.*, p. 697.

[4] *Ibid.*, p. 699.

The revisions recommended in these specifications are as follows:

Title.—Change to read as follows by the omission of the words in brackets:

"Tentative Specifications for Quicklime [and Hydrated Lime] for Use in the Manufacture of Sulfite Pulp."

Section 2.—Change from its present form: namely,

"(*a*) Either quicklime or hydrated lime may be used.[a] Either calcium or magnesian lime may be used, but owing to the greater solubility and reactivity of magnesian bisulfite, high magnesian lime gives the best results. The ratio of MgO to CaO shall be reasonably constant and the lime shall be moderately free from impurities. The lime shall be of such a physical nature that it will form a rapid settling sludge.

"(*b*) The quicklime or hydrated lime shall conform to the following requirements as to chemical composition, calculated to the non-volatile basis:

Calcium oxide (CaO) and Magnesium oxide (MgO), minimum... 94 per cent

Iron Oxide (Fe_2O_3), aluminum oxide (Al_2O_3), Silicon oxide (SiO_2) and insoluble matter, maximum.......................... 3 "

Carbon dioxide, maximum:

(*a*) If sample is taken at place of manufacture............. 5 "

(*b*) If sample is taken at other than place of manufacture... 10 " "

to read as follows:

"(*a*) Either calcium or magnesium lime may be used, but owing to the greater solubility and reactivity of magnesium bisulfite, high magnesium lime gives the best results. The ratio of MgO to CaO shall be reasonably constant and the lime shall be moderately free from impurities. The lime shall be of such a physical nature that it will form a rapid settling sludge.

"(*b*) The quicklime shall conform to the following requirements as to chemical composition, all percentages to be based on the weight of the sample taken at the point of manufacture:[b]

	CALCIUM LIME		MAGNESIUM LIME	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
Calcium Oxide, per cent...........	....	92.5	....	55.4
Magnesium Oxide, per cent.........	2.5	....	....	39.6
Oxides of Silicon, Iron and Aluminum, per cent......................	3.0	....	3.0	....

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[a] Quicklime is more commonly used.

[b] If it is desired to use the non-volatile basis the figures given above should be changed to the following:

	CALCIUM LIME		MAGNESIUM LIME	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
Calcium Oxide, per cent...................	....	94.3	....	56.5
Magnesium Oxide, per cent	2.6	....	....	40.4
Oxides of Silicon, Iron and Aluminum, per cent	3.1	....	3.1	....
Carbon Dioxide, per cent	5.0	....	5.0	....

The Tentative Specifications for Hydrated Lime for the Manufacture of Varnish (C 47 – 22 T) have been submitted to Committee C-7 with the recommendation that they be continued as tentative, with minor editorial changes.

Proposed Tentative Specifications for Quicklime for Use in Water Treatment, appended hereto,[1] have been submitted to Committee C-7, with the recommendation that they be adopted as tentative.

Proposed Tentative Specifications for Hydrated Lime for Use in Water Treatment, appended hereto,[2] have also been submitted to Committee C-7, with the recommendation that they be adopted as a tentative standard.

Specifications for lime for use in the manufacture of glass, sand-lime brick, ceramic whiting, bleaching powder, sugar, calcium arsenate, and leather, and for use in causticizing and gas purification, are under consideration by the Coordinating Committee and Sub-Committee III.

Sub-Committee IV on Agricultural Lime.—This sub-committee has continued its study of solubility of liming materials and of the use of lime in crop protection work.

Sub-Committee V on Methods of Analysis.—This sub-committee has considered the revision of the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (C 50 – 23 T)[3] and has found it necessary to re-write these methods. The sub-committee has recommended to Committee C-7 that the revised methods, appended hereto,[4] be accepted for publication as tentative to replace the present methods.

The Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (C 25 – 22 T) have been submitted to Committee C-7, with the recommendation that they be continued as tentative, with certain minor editorial changes in the method for determination of available lime.

The following definition of the term "in bulk" as applying to lime and lime products has been submitted to Committee C-7, with the recommendation that it be accepted as a tentative definition:

> "Lime or lime products are 'in bulk' when it or they exist *en masse* in bins, in piles, or in transporting vehicles."

The sub-committee received a paper on "Electrical Resistance Methods for the Determination of the Time of Set of Lime Plaster," by John W. Stockett, Jr., a fellow of the National Lime Association at the U. S. Bureau of Standards, and recommended that it be published as an appendix to the Report of Committee C-7 as a matter of record and information for subsequent use.

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[1] See p. 809.—ED.

[2] See p. 811.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 636 (1923).

[4] See p. 844.—ED.

Sub-Committee VI on Plasticity has completed its work of calibrating plasticimeters.

A preliminary survey of the second function of the sub-committee—the investigation of the cause of plasticity—led to the conclusion that such an investigation would involve the study of many correlated properties, most of which are probably outside the jurisdiction of the sub-committee. It was accordingly decided to ask that this sub-committee be merged with Sub-Committee V, to form a new Sub-Committee V on Methods of Test of Lime and Lime Products.

Sub-Committee VII on Lime for Highways reported continued progress in the work mentioned in the 1923 Annual Report of Committee C-7, but as yet is not prepared to make definite recommendations.

Sub-Committee VIII on Nomenclature has recommended to Committee C-7 that it accept the recommendations of Committee E-8 on Nomenclature and Definitions in reference to the Tentative Definitions of Terms Relating to Lime (C 51 – 22 T).[1] The revisions recommended in these definitions are as follows:

Change the definition of "hydrated lime" from its present form: namely,

> "A dry powder made by treating quicklime with enough water to satisfy its chemical affinity under the conditions of its hydration. It consists essentially of calcium hydroxide or of a mixture of calcium hydroxide and magnesium oxide and magnesium hydroxide."

to read as follows:

> "A dry powder obtained by treating quicklime with water enough to satisfy its chemical affinity under the conditions of its hydration.
>
> "NOTE.—It consists essentially of calcium hydroxide or a mixture of calcium hydroxide and magnesium oxide and magnesium hydroxide."

Change the definition of "lump lime screened" from its present form: namely,

> "Lump lime which has been screened or forked so that all of the pieces will be retained on a ½-in. sieve."

to read as follows:

> "Lump lime after forking or screening to remove the portion which will pass a ½-in. sieve."

Change the definition of "pulverized lime," reading as follows:

> "Lump lime which is of such size that it will all pass a No. 3 sieve."

to read:

> "Quicklime which will pass a ¼-in. sieve."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 731 (1922).

Sub-Committee VIII concurred in the recommendation of Sub-Committee V on the term "in bulk" previously referred to, and recommended that it be accepted as a tentative definition.

Committee C-7 recommends the adoption by the Society of the several recommendations contained in this report and tabulated below with the results of the letter ballot vote of the committee:

Items	Affirmative	Negative	Not Voting
I. TENTATIVE SPECIFICATIONS TO BE ADVANCED TO STANDARD			
1. Hydrated Lime for Structural Purposes (C 6 – 23 T)	30	1	6
2. Quicklime and Hydrated Lime for Use in the Textile Industry (C 48 – 22 T)	20	1	16
3. Quicklime and Hydrated Lime for the Manufacture of Silica Brick (C 49 – 22 T)	24	0	13
II. REVISIONS OF TENTATIVE STANDARDS			
4. Quicklime for Structural Purposes (C 5 – 22 T)	26	0	11
5. Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper (C 45 – 22 T)	25	0	12
6. Quicklime and Hydrated for Use in the Manufacture of Sulfite Pulp (C 46 – 22 T)	22	1	14
7. Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (C 50 – 23 T)	30	1	6
8. Definitions of Terms Relating to Lime (C 51 – 22 T)	29	0	8
III. SUBMISSION OF NEW TENTATIVE SPECIFICATIONS			
9. For Quicklime for Use in Water Treatment	21	3	13
10. For Hydrated Lime for Use in Water Treatment	19	4	14

Committee C-7 has accepted the definition of the term "in bulk" as submitted by Sub-Committees V and VIII, and recommends that it be transmitted to Committee E-8 for approval.

The paper by J. W. Stockett, Jr., referred to above under the recommendations of Sub-Committee V, is appended hereto.

This report has been submitted to letter ballot of the committee, which consists of 37 members, of whom 30 have voted affirmatively, none negatively, and 7 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. C. BERRY,
Chairman.

R. P. BROWN,
Secretary.

EDITORIAL NOTE

The Tentative Specifications for Hydrated Lime for Structural Purposes, for Quicklime and Hydrated Lime for Use in the Textile Industry and for Quicklime and Hydrated Lime for the Manufacture of Silica Brick were approved at the annual meeting, as recommended in this report, and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Quicklime for Structural Purposes, for Quicklime and Hydrated Lime for Use in the Cooking of Rags, for Quicklime and Hydrated Lime for Use in the Manufacture of Sulfite Pulp, the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products and the Tentative Definitions of Terms Relating to Lime, recommended in this report, were accepted. The tentative standards, as thus revised, appear on pages 802–808, 844–848.

The proposed Tentative Specifications for Quicklime for Use in Water Treatment and for Hydrated Lime for Use in Water Treatment, referred to in this report, were accepted for publication as tentative, with the revisions given on page 24 of the Summary of Proceedings, and appear on pages 809–812.

APPENDIX

ELECTRICAL RESISTANCE METHODS FOR THE DETERMINATION OF THE TIME OF SET OF LIME PLASTER

By J. W. Stockett, Jr.[1]

The investigation, which was carried out at the U. S. Bureau of Standards, had for its purpose the development of a method for the determination of the time of set of lime plaster. The set of lime plaster, or its readiness for another coat, is dependent upon two conditions: namely, its state of rigidity and its degree of dryness. Plaster must develop a certain state of rigidity in order to withstand the pressure exerted in applying a second coat. It is equally important that the plaster should attain a certain degree of dryness in order to develop the necessary suction for the application of a second coat. The penetration method for the determination of the time of set, described in the Society's Standard Specifications and Tests for Portland Cement (C 9 - 21) is a method for measuring rigidity. This method is satisfactory for the determination of the time of set of materials such as calcined gypsum and portland cement which develop rigidity rapidly. Lime plaster develops rigidity slowly and consequently the end point as indicated by the penetrometer is indefinite. Furthermore, the penetrometer is not satisfactory for the determination of the time of set of sanded plasters.

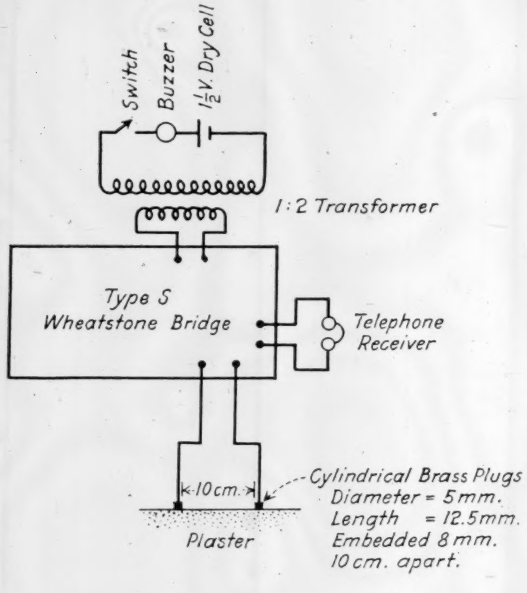
Switch
Buzzer
1½ V. Dry Cell
1:2 Transformer
Type S
Wheatstone Bridge
Telephone
Receiver
10 cm.
Cylindrical Brass Plugs
Diameter = 5 mm.
Length = 12.5 mm.
Embedded 8 mm.
10 cm. apart.
Plaster

Fig. 1.—Schematic Diagram for Electrical Resistance Method of Determining Time of Set.

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[1] Fellow of the National Lime Association at the U. S. Bureau of Standards, Washington, D. C.

Since drying is a function of the setting of lime, it was proposed to measure the rate of drying of the plaster by means of electrical resistance determinations, the electrical resistance of plaster increasing as the material drys. A Leeds & Northrup, Type S, Wheatstone bridge was used, the set-up being as shown in Fig. 1, similar to that used in making conductivity determinations of electrolytes. The freshly prepared plaster was spread on a glass plate and made into a pat measuring 20 by 8 by 1 cm. Cylindrical brass plugs, 5 mm. in diameter and 12.5 mm. in length, embedded 8 mm. in the plaster, served as electrodes. The plugs were spaced 10 cm. apart. The lead wires were soldered to the exposed ends of the plugs. Resistance determinations were made at noted intervals of time and the results plotted.

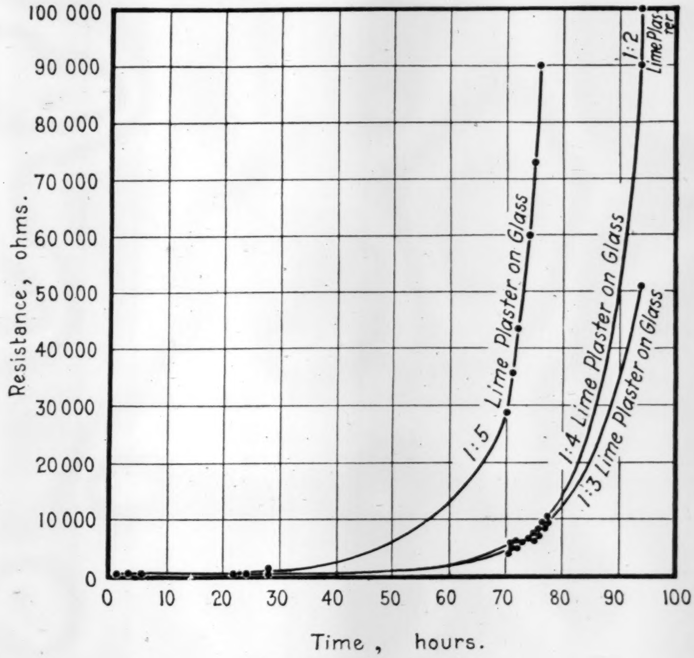

FIG. 2.—Electrical Resistance Measurements on Lime Plasters.

Fig. 2 shows the curves obtained with samples of lime plaster prepared with various proportions of sand. The general characteristics of the curves are the same irrespective of the proportions of sand used. The slopes of the curves increase rapidly at the time when the samples appear to be set as judged by eye. The steepness of the slope during the setting period of the samples is indicative of the sensitivity. From the curve for 1:5 plaster of Fig. 2, it will be noted that at $70\frac{1}{2}$ hours the resistance equals 30,000 ohms and at $71\frac{1}{2}$ hours the resistance is 40,000 ohms, an increase of 10,000 ohms per hour. Since at this point the instrument may be read accurately to 1000 ohms, it is seen that the method is capable of indicating changes in the condition of the plaster for six-minute intervals of time. An arbitrary value of 30,000 ohms may be assumed as the point of set.

An experiment was made to determine the effect upon the resistance readings of plastering the material upon an electrical conductor such as metal lath. It was noted that when the samples had the same appearance of set, the resistance readings were much less in the case of the material plastered on metal lath compared with simultaneous readings of the same material spread on a glass plate. The method as developed to date is not applicable for measuring the time of set of lime plaster on metal.

Resistance determinations were made on a sample of lime plaster containing 1 per cent of sodium chloride by weight of the hydrate. The readings on this sample were less than those obtained with a similar mixture containing no sodium chloride. Fig. 3 shows the comparison of determinations made upon samples of 1:3 hydrate and 1:3 hydrate plus 1 per cent NaCl, on glass plates.

When lime plaster is applied to wood lath, the lath absorbs a saturated solution of lime water from the plaster and becomes an electrical conductor. If the wet wood lath should become a better conductor than the plaster, the results would be in error and the observed time of set would be more than that obtained for a similar sample of plaster applied to a glass plate. Accordingly, a batch of 1:5 lime plaster was prepared, a portion of which was applied to wood lath which had previously been wetted and the remainder spread on a glass plate. The pats were spread to the same thickness in each case and the electrodes were embedded until they made contact with the backing. Simultaneous readings of resistance were made. The results as plotted in Fig. 4 show that a 1:5 lime plaster on wood lath sets much quicker than a 1:5 lime plaster on a glass plate. This comparison indicates that the resistance of the wet wood lath is not of a nature to affect the results.

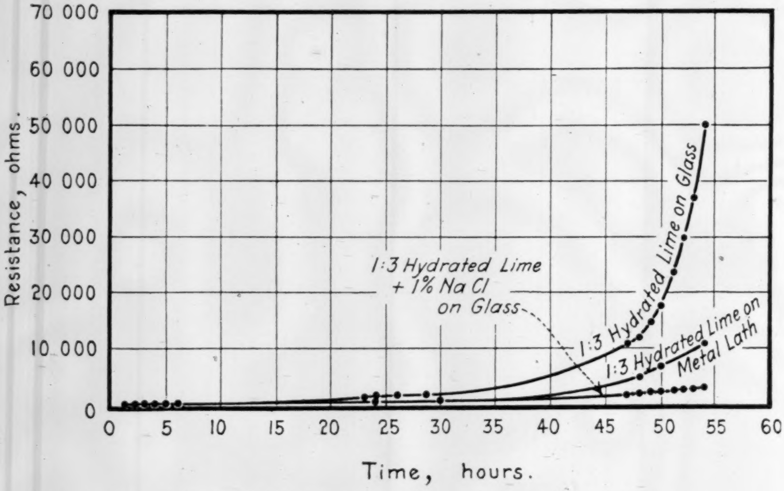

FIG. 3.—Electrical Resistance Measurements on Lime Plasters.

A 1:10 lime plaster and a 1:5 lime plaster, both on glass plates, were compared to determine if the rate of drying was increased with the proportions of sand used. As shown in Fig. 4, the rates of drying of the two samples are very nearly the same, the 1:5 mixture drying somewhat more rapidly. However, several additional comparisons showed that sometimes the 1:10 mixture dries more rapidly. It is to be concluded, therefore, that there is very little difference in the rates of drying of a 1:5 and a 1:10 lime plaster.

It will be noted that the rate of drying of the 1:5 lime plaster shown in Fig. 4 is much greater than that of the 1:5 mixture shown in Fig. 2, although the two samples were applied to the same backing. This difference is explained by the fact that the determinations were made on different days and that the variation in atmospheric conditions affected the results.

CONCLUSIONS

Electrical resistance measurements afford a method for the determination of the time of set of lime plaster.

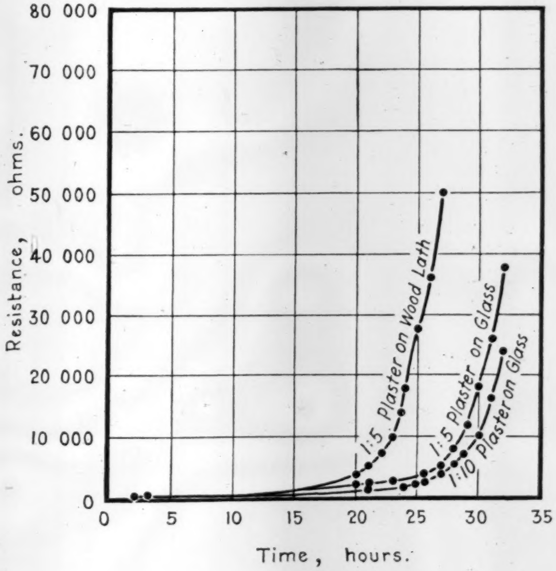

FIG. 4.—Electrical Resistance Measurements on Lime Plasters.

The presence of soluble chlorides in the plaster interferes with the time of set determinations. However, soluble chlorides are rarely encountered in practice in quantities sufficient to affect the results. The occurrence of sodium chloride in quantities equivalent to 1 per cent of the hydrate is exceptional and would be deleterious to the plaster, causing efflorescence.

The method is applicable to plasters carrying different proportions of sand.

The method is accurate, easy to manipulate and sensitive to the end point.

Determinations can be made on a number of samples at the same time.

Electrical resistance determinations indicate that lime plaster, on a nonmetallic base, is set when a reading of 30,000 ohms is obtained under the conditions as outlined above.

REPORT OF COMMITTEE C-9

ON

CONCRETE AND CONCRETE AGGREGATES

During the past year, Committee C-9 held two meetings at which the work of the various sub-committees was considered. A number of changes in sub-committee personnel have been made with the idea of expediting progress. The committee can present no conclusions nor suggest any standards at the present time in view of the inconclusive status of the projects under way in its various sub-committees.

Sub-Committee I on Definitions has been at work, in conjunction with Committee E-8 on Nomenclature and Definitions, on definitions for the terms "sand," "sieve," and "screen." The chairman of this sub-committee has likewise been acting with a sub-committee of Committee E-8 in the formulation of definitions relating to clay.

Sub-Committee II on Laboratory Tests for Concrete and Design of Concrete Mixtures proposes to attempt the analysis of existing data in order to arrive at the degree of accuracy to be expected from the important theories which have been advanced during the past few years.

Sub-Committee IV on the Relative Values of Various Strength Tests has presented a progress report involving work done at the University of Maine in which application is made of a statistical method for the analysis of test data. One of the important tests which this sub-committee should investigate most actively in the future is the so-called strength ratio test. Considerable discussion has been had in the past few years as to the usefulness of this test for determining the concrcte making properties of fine aggregates.

Sub-Committee VII on Specifications and Methods of Tests of Coarse Aggregates has outlined a program of work to be undertaken in order to arrive at reasonable specifications for coarse aggregates. One of the most important tests for this sub-committee to develop is a test for determining the probable durability of coarse aggregates.

No further progress has been made on specifications for concrete. This is due in part to the fact that it is necessary to develop standard specifications for aggregates and other standards before specifications for concrete can be written.

Although no particular report on admixtures is available at the present time, Sub-Committee XI on Admixtures will have the results of long-time tests to present in the near future.

Committee C-9 aims to have specifications for concrete and concrete aggregates to the end that the proper precautions might be taken to secure concrete of suitable quality for the purposes for which it is intended. The writing of such specifications must be based on knowledge which at the present time is quite incomplete and will necessitate investigations being undertaken or information collected on questions of which the following are typical:

1. Durability of Concrete.
   The effect on durability of:
   (*a*) The quality of aggregates including:
      (1) Surface Texture;
      (2) Absorption;
      (3) Physical properties;
      (4) Chemical or petrographic composition.
   (*b*) Density of concrete;
   (*c*) Repeated freezing and thawing, moisture and temperature;
   (*d*) Repeated stress;
   (*e*) Alkali and sea water.
2. Development of suitable laboratory tests for fine aggregate which will differentiate between sands of good quality and sands of poor quality.
3. The use of screenings as a substitute for natural sand as a fine aggregate in concrete and the effect on the strength, durability and other properties of concrete.
4. Study of methods for the rapid hardening of concrete.
5. Studies of admixtures and their effect on the workability of concrete.
6. Studies of the bulking effect of moisture in sand and the proper means for allowing for this effect in specifications for proportioning concrete.
7. Elastic properties of concrete under impact.

Some of the above topics are now being studied; others are contemplated for investigation in the near future.

This report has been submitted to letter ballot of the committee, which consists of 44 members, of whom 36 have voted affirmatively, none negatively, and 8 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. T. GOLDBECK,
Chairman.

J. C. PEARSON,
Secretary.

ADDENDUM TO REPORT OF COMMITTEE C-9

At a meeting of Committee C-9, held on June 26, 1924, action was taken to revise the table of requirements for size of wire and sieve openings with tolerances thereon, appearing in the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 22)[1] to agree with the requirements submitted by Committee E-1 on Methods of Testing and appearing in the report of that committee. This action was approved by unanimous vote.

The definitions of terms relating to specific gracity, submitted in the Report of Committee E-8 on Nomenclature and Definitions, were also approved, as was the definition for the term "fineness" submitted by Committee D-1 on Preservative Coatings for Structural Materials.

Respectfully submitted,

A. T. Goldbeck,
Chairman.

J. C. Pearson,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Method of Test for Sieve Analysis of Aggregates for Concrete, appearing in the addendum to this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The method, as revised, appears in the 1924 Book of A.S.T.M. Standards.

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[1] A.S.T.M. Standards Adopted in 1922.

REPORT OF COMMITTEE C-10
ON
HOLLOW BUILDING TILE

This committee has held three meetings during the year, has revised two existing tentative standards and is submitting two new standards for acceptance as tentative.

The membership has been increased to 20, of which 11 are non-producers and 9 are producers. Further addition to the membership should have in view the obtaining of representation for industrial groups producing hollow tile but not represented on the committee and for whose product specifications will have to be drafted. The committee functions in part through several sub-committees concerned with the various properties or forms of the material, to some of whom the initial formulation of specifications is assigned. The committee has been active in this field during the past year and has developed provisions for standards that nearly cover the range of form and purpose of the burnt-clay product.

Through the well-directed efforts of the sub-committee on increase of Society membership, 22 new members have been obtained.

The following recommendations to the Society relative to standards under the jurisdiction of Committee C-10 are made:

No. 1. *Tentative Definitions of Terms Relating to Hollow Tile (C 43 - 23 T)*.[1]—Some minor changes have been made in the tentative definitions submitted last year, relative to which we have had the benefit of contact with Committee E-8 on Nomenclature and Definitions, and in the form reported are apparently satisfactory to both committees. They are now recommended for adoption as appended hereto.[2]

No. 2. *Tentative Specifications for Clay Hollow Building Tile (C 34 - 21 T)*.[3]—The present specifications have been rewritten and are appended hereto[4] in their proposed revised form, under the title "Tentative Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile."

(*a*) *Classification.*—It was found desirable to classify tile into the three classes, hard, medium, and soft, instead of giving one set of

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 640 (1923).

[2] See 1924 Book of A.S.T.M. Standards.—Ed.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 547 (1921).

[4] See p. 818.—Ed.

TABLE I. SUMMARY OF RESULTS OF COMPRESSION AND ABSORPTION TESTS.

Laboratory Identification	Kind of Clay	Number of Tests	Nominal Size, in.	Number of Cells	Position in which Tested	Weight, lb.		Compressive Strength				Absorption, per cent	
								Lb. per sq. in. of Gross Area		Lb. per sq. in. of Net Area			
						Total	Per cu. in.	Range	Average	Range	Average	Range	Average
A	Shale	4	8 by 12 by 12	4	End	27.76	0.0741	1180 to 1800	1509	3590 to 5770	4838	6.6 to 12.4	8.44
	Shale	3	8 by 12 by 12	4	Edge	.....	......	390 to 560	490	2080 to 3030	2643	6.0 to 12.3	7.52
G	50 per cent fire clay, 50 per cent shale	5	8 by 12 by 12	4	End	32.71	0.0744	1200 to 2200	1606	3180 to 6070	4327	6.9 to 11.1	8.91
	50 per cent fire clay, 50 per cent shale	4	8 by 12 by 12	4	Edge	.....	......	890 to 1160	975	3900 to 5430	4483	8.6 to 9.8	9.36
F	Fire clay containing 15 per cent shale	5	8 by 12 by 12	4	End	28.41	0.0688	1080 to 1970	1520	3000 to 5920	4454	10.9 to 13.7	12.39
	Fire clay containing 15 per cent shale	3	8 by 12 by 12	4	Edge	.....	......	290 to 360	314	1280 to 1700	1468	12.1 to 13.5	12.48
O	Surface clay	5	8 by 12 by 12	4	End	28.93	0.0605	680 to 1290	978	1600 to 3080	2304	22.7 to 25.8	24.85
	Surface clay	5	8 by 12 by 12	4	Edge	28.89	......	310 to 690	424	1160 to 2480	1554	22.7 to 25.6	24.07
C	Shale	3	8 by 12 by 12	6	End	28.54	0.0814	1280 to 1480	1362	4040 to 4570	4288	7.7 to 11.0	8.99
	Shale	3	8 by 12 by 12	6	Edge	.....	......	330 to 400	361	1610 to 2030	1825	8.1 to 12.5	9.71
D	Shale	5	8 by 12 by 12	6	End	35.49	0.0792	1970 to 3450	2826	4700 to 8230	6821	6.4 to 10.9	8.47
	Shale	5	8 by 12 by 12	6	Edge	.....	......	1260 to 1930	1557	5430 to 8220	6667	7.1 to 10.6	8.56
	Shale	5	8 by 12 by 12	6	End	36.61	0.0821	2730 to 3520	3150	6740 to 8610	7683	5.8 to 7.5	6.89
L	Dense-burning fire clay	5	8 by 12 by 12	6	End	34.70	0.0715	1590 to 3010	2546	3830 to 7130	6118	10.8 to 15.0	11.92
	Dense-burning fire clay	5	8 by 12 by 12	6	Edge	35.52	0.0719	850 to 1090	989	3780 to 4810	4320	10.6 to 12.5	11.89
	Dense-burning fire clay	5	8 by 12 by 12	6	End	35.26	......	2610 to 3110	2897	5950 to 7100	6598	10.5 to 12.4	11.47
	Dense-burning fire clay	5	8 by 12 by 12	6	Edge	35.14	......	850 to 1160	978	3800 to 5180	4385	9.6 to 14.0	11.69
M	Dense-burning fire clay	5	8 by 12 by 12	6	End	.....	......	2450 to 2980	2681	6110 to 7420	6691	7.6 to 11.0	8.65
	Dense-burning fire clay	5	8 by 12 by 12	6	Edge	32.30	......	600 to 1000	776	3140 to 5230	4076	5.7 to 10.4	8.12
N	Open-burning fire clay	5	8 by 12 by 12	6	End	30.77	0.0681	1780 to 2720	2250	4440 to 6560	5103	8.7 to 14.5	12.29
	Open-burning fire clay	5	8 by 12 by 12	6	Edge	30.95	......	460 to 680	581	2080 to 3300	2722	8.7 to 13.0	11.14
P	Open-burning fire clay	5	8 by 12 by 12	6	End	34.98	0.0687	1230 to 2020	1675	2710 to 4460	3704	11.0 to 15.7	12.85
	Open-burning fire clay	5	8 by 12 by 12	6	Edge	35.86	......	470 to 610	544	1980 to 2620	2359	12.2 to 15.6	13.62
H	Open-burning fire clay	5	8 by 12 by 12	6	End	33.81	0.0682	1090 to 1570	1408	2350 to 3330	3042	14.5 to 17.2	15.61
	Open-burning fire clay	3	8 by 12 by 12	6	Edge	.....	......	310 to 370	336	1090 to 1310	1192	15.2 to 17.0	15.81
K	Surface clay	5	8 by 12 by 12	6	End	33.60	0.0660	1370 to 2040	1510	3030 to 4340	3213	7.8 to 19.2	15.07
	Surface clay	3	8 by 12 by 12	6	Edge	.....	......	280 to 440	355	970 to 1440	1193	11.4 to 17.4	13.57
Y	Surface clay	5	8 by 12 by 12	6	End	33.85	0.0677	1810 to 2240	1900	4370 to 5360	4872	15.0 to 17.6	16.20
	Surface clay	5	8 by 12 by 12	6	Edge	33.82	0.0668	390 to 640	516	1980 to 3290	2538	16.1 to 17.3	16.74

TABLE I—*Continued.* SUMMARY OF RESULTS OF COMPRESSION AND ABSORPTION TESTS.

Laboratory Identification	Kind of Clay	Number of Tests	Nominal Size, in.	Number of Cells	Position in which Tested	Weight, lb.		Compressive Strength				Absorption, per cent	
								Lb. per sq. in. of Gross Area		Lb. per sq. in. of Net Area			
						Total	Per cu. in.	Range	Average	Range	Average	Range	Average
Q	Surface clay	5	8 by 12 by 12	6	End	32.40	0.0741	1890 to 3870	2639	4490 to 11075	6644	2.4 to 15.3	9.79
	Surface clay	4	8 by 12 by 12	6	Edge	33.74	......	410 to 540	493	1810 to 2690	2296	16.0 to 17.7	16.88
J	Surface clay	5	8 by 12 by 12	6	End	40.86	0.0644	1300 to 1670	1473	2345 to 3180	2761	16.2 to 20.8	19.02
	Surface clay	5	8 by 12 by 12	6	Edge	41.10	......	520 to 890	710	1520 to 2970	2253	14.7 to 23.1	19.43
	Surface clay	5	8 by 12 by 12	9	End	34.51	0.0609	580 to 1440	1050	1100 to 2740	2019	16.8 to 24.4	21.39
D	Shale	5	4 by 12 by 12	3	End	19.83	0.0805	4720 to 5640	5304	10180 to 12200	11349	6.4 to 7.5	7.02
	Shale	5	4 by 12 by 12	3	Edge	20.08	0.0789	2240 to 3070	2630	7860 to 10580	9216	7.2 to 9.6	8.87
L	Dense-burning clay	5	4 by 12 by 12	3	End	18.23	0.0742	3310 to 4570	4060	7450 to 10610	9197	8.2 to 11.0	9.42
	Dense-burning clay	5	4 by 12 by 12	3	Edge	18.14	0.0744	1530 to 2300	1861	6030 to 8810	7141	7.6 to 10.3	9.01
J	Surface clay	5	4 by 12 by 12	3	End	16.79	0.0595	940 to 1520	1921	1920 to 3230	2689	25.0 to 26.5	25.64
	Surface clay	5	4 by 12 by 12	3	Edge	16.69	......	510 to 740	596	1630 to 2390	1932	24.8 to 27.0	26.11
	Surface clay	5	4 by 12 by 12	3	End	18.46	0.0599	1110 to 1990	1654	2320 to 3720	3102	23.6 to 25.4	24.77
	Surface clay	5	4 by 12 by 12	3	Edge	18.54	......	490 to 1240	807	1350 to 3500	2229	23.4 to 25.5	24.53
B	Shale	3	8 by 5 by 12	3	Side	15.04	......	690 to 750	721	2920 to 3490	3227	1.4 to 18.1	11.92
C	Shale	5	8 by 5 by 12	3	Side	16.03	......	840 to 1020	914	3180 to 3940	3457	9.0 to 14.4	10.50
D	Shale	5	8 by 5 by 12	2	Side	14.54	0.0743	1290 to 1620	1376	5350 to 6680	5730	8.6 to 10.9	10.09
E	Shale	5	8 by 5 by 12	2	Side	15.29	0.0703	570 to 880	690	2390 to 4050	2967	11.1 to 14.8	13.39
L	Dense-burning fire clay	2	8 by 5 by 12	2	Side	14.84	0.0746	1030 to 1700	1365	4610 to 7160	5886	6.4 to 8.6	7.77
M	Dense-burning fire clay	2	8 by 5 by 12	3	Side	16.09	......	610 to 950	731	2830 to 4270	3336	6.8 to 10.3	8.74
R	50 per cent shale, 50 per cent surface clay	5	8 by 5 by 12	2	Side	13.42	0.0727	1150 to 1450	1273	5370 to 6700	5885	10.2 to 12.0	10.83
HO	Surface clay	11	8 by 5 by 12	3	Side	15.05	......	600 to 1060	767	1800 to 3080	2309	24.1 to 26.1	25.11
ST	Surface clay	12	8 by 5 by 12	3	Side	14.79	......	730 to 1480	1000	2440 to 5040	3372	12.8 to 16.8	14.40
BA	Dense-burning fire clay	25	8 by 5 by 12	2	Side	14.92	......	860 to 1620	1182	3570 to 6640	4855	6.9 to 16.3	11.55
MC	Shale	5	Denison H No. 47	...	Side	30.67	0.0686	410 to 860	644	1430 to 2980	2239	10.5 to 15.4	12.66
L	Dense-burning fire clay	10	Denison H	...	Side	32.55	......	990 to 1740	1439	3540 to 6270	5113	8.9 to 12.4	10.54
PB	Shale	10	Interlocking	...	Side	15.12	......	840 to 1530	1259	3240 to 6200	4954	6.8 to 15.3	11.38
CP	Fire clay	10	Interlocking	...	Side	17.81	......	860 to 1580	1156	3380 to 5680	4407	4.1 to 10.2	6.41
FR	Open-burning fire clay	8	Interlocking	...	Side	17.75	......	1280 to 1640	1425	3500 to 4300	3861	9.0 to 13.1	10.62
FR	Surface clay	10	Interlocking	...	Side	18.31	......	840 to 1130	942	2770 to 3740	3141	9.7 to 15.3	12.95
Y	Surface clay	10	Interlocking	...	Side	14.74	......	450 to 670	559	1670 to 2690	2231	11.6 to 15.3	13.45
	Surface clay	10	Interlocking	...	Side	14.67	......	540 to 930	691	2110 to 3800	2819	7.4 to 9.7	8.62

minimum requirements that would apply primarily only to what is now termed the soft grade. By this classification, selection for given purposes can be made and better utilization is made possible of the range of product available.

Table I gives a summary of results of compression and absorption tests made at the U. S. Bureau of Standards of hollow partition and load-bearing tile as a part of the investigation of the properties of hollow tile conducted in cooperation with the Hollow Building Tile Association, the results of which have been made available to this committee. Tile from representative regions, kinds of clay, and forms of unit are included and the specification requirements are in large part based on these test results.

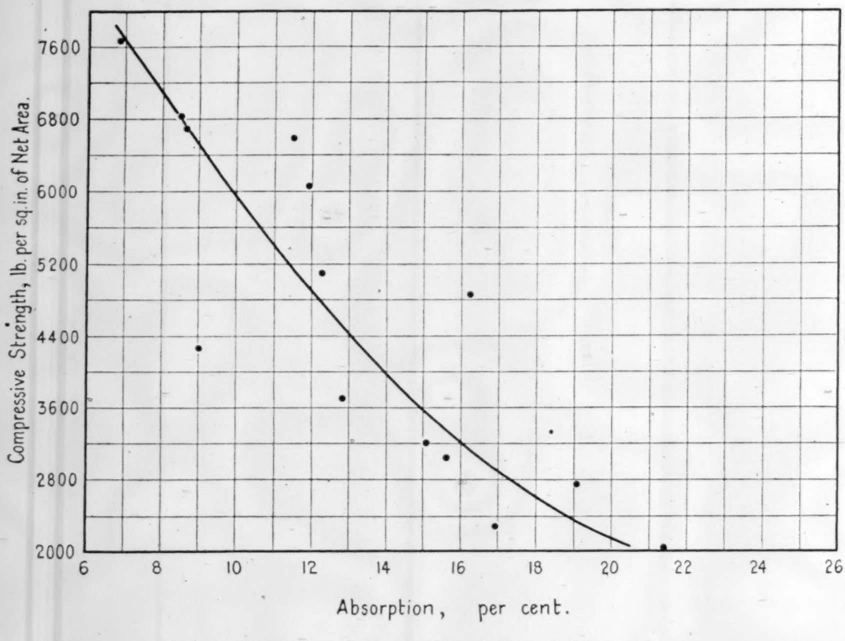

FIG. 1.—Relation between Strength and Absorption.

(*b*) *Weight.*—The weights specified are a little heavier than the average of those tested but conform with recent standards set by the industry and with the Simplified Practice Recommendations of the U. S. Department of Commerce.

(*c*) *Strength, Absorption and Weight Relations.*—Group averages of results of end-construction tile tested on end in compression are plotted in Fig. 1 against the percentage absorption determined by boiling in water at atmospheric pressure. A decided trend of increase in strength with decrease in absorption is seen although not without marked exceptions. Thus, tile having 12 per cent or less absorption can be expected to develop an average compressive strength of 4400 or more pounds per square inch of net area, which means 1800 or more pounds per square inch of gross area, which are the strength and absorption limits for hard tile under these specifications. Similarly, in the range from 12 to 16 per cent absorption, a compressive strength from 4400 to 3200 lb. per sq. in. of net area, or approximately 1800 to 1400 lb. per sq. in. of gross area is to be expected, this being the range in properties of medium tile, which define by their lower strength limit the upper limit for soft tile.

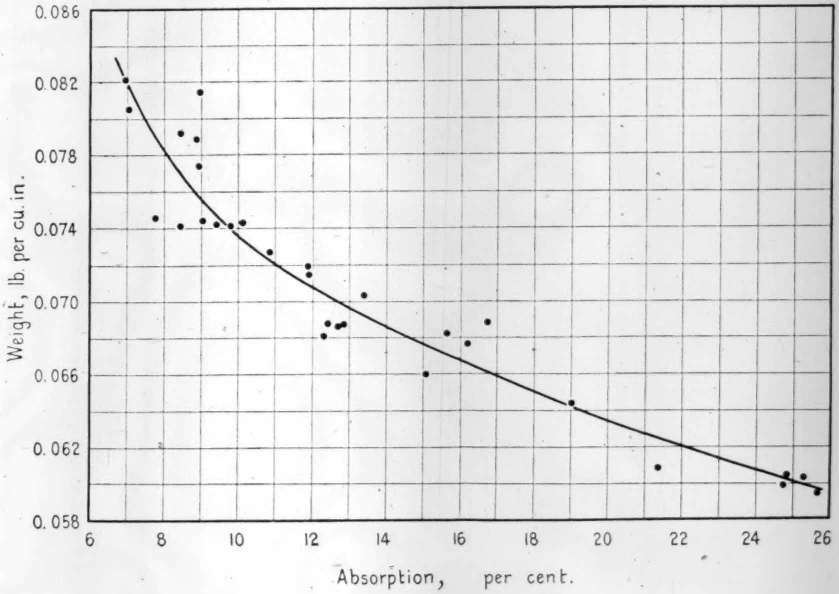

FIG. 2.—Relation between Unit Weight of Constituent Material in Tile and Absorption.

Fig. 2 shows a fairly consistent variation of percentage absorption with weight per cubic unit of burnt material. This is to be expected since the amount of closed pore space in the burnt-clay material is small, and the true specfic gravities of the materials increase consistently from about 2.6 for the more porous burning clays to 2.8 for the densest burning material generally obtaining in hollow tile manufacture.

Fig. 3 gives indication of what may be expected in the way of a connection between the total weight of the unit and the unit gross area strength. The points plotted are group values for 8 by 12 by 12 in. end-construction tile tested on end, the curve being drawn only with reference to values for dense-burning fire-clay tile and for shale tile. For surface-clay and open-burning fire-clay tile, variations in the clay material and structure of the burnt product are too large to permit any consistent relation between strength and weight to obtain. The weight of the unit, while a doubtful criterion of the strength, is a measure of the mass present, which is an approximate criterion of fire resistance as applied to tile of a given type of clay, and of insulation against heat and cold at ordinary temperatures for a given hollow tile design. Certain thicknesses of shell and webs are necessary to secure sufficient bearing area on mortar joints in the masonry and it is believed that such area is best obtained through a weight requirement since it allows greater freedom in the design of the unit.

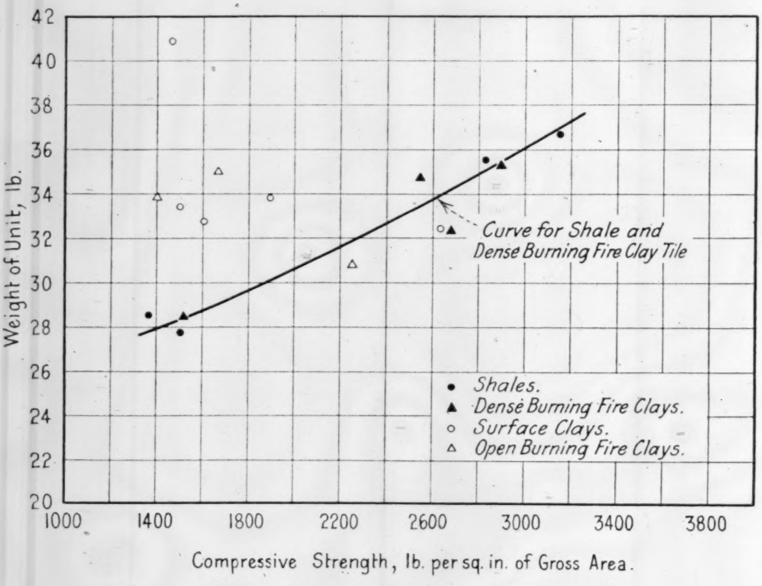

FIG. 3.—Weight-Strength Relations of Hollow Tile.

In Fig. 4 a fairly consistent variation of modulus of elasticity with compressive strength is evident, up to a value of 4,000,000 lb. per sq. in., after which there is little increase in its value for tile of higher strength. The results were obtained with end-construction tile tested on end. The modulus of elasticity remains nearly constant until failure is approached with the harder tile. With less dense tile there is a more noticeable decrease in its value after one-half to three-fourths of the ultimate load is applied. The values plotted are of the average tangent to the initial part of the curve.

(*d*) *Weathering Resistance.*—The requirement of a resistance, equivalent to that necessary to withstand 100 cycles of alternate freezing and thawing in the saturated condition, is based on results of freezing tests checked by observation of weathering effects on tile in buildings. The freezing tests conducted at the Bureau of Standards, the results of which are summarized in Table II, indicate that almost all tile will withstand 60 freezing cycles without noticeable effects. Experience with tile as exposed in buildings indicated that satisfactory performance is not given under severe conditions by all tile passing this requirement, but no records of unsatisfactory service have been obtained of well-burnt tile classified as medium by these specifications, and having absorption of not more than 16 per cent. Such tile in the tests withstood acceptably 100 alternations of freezing and thawing and, having passed this mark, all but a few withstood 50 to 100 additional cycles without failure. While the interpretation of results of tests in terms of actual weathering resistance must be made with caution, the present indications are that tile withstanding the 100 alternations has satisfactory weathering properties, and that well-burnt tile graded as hard or medium under these specifications will

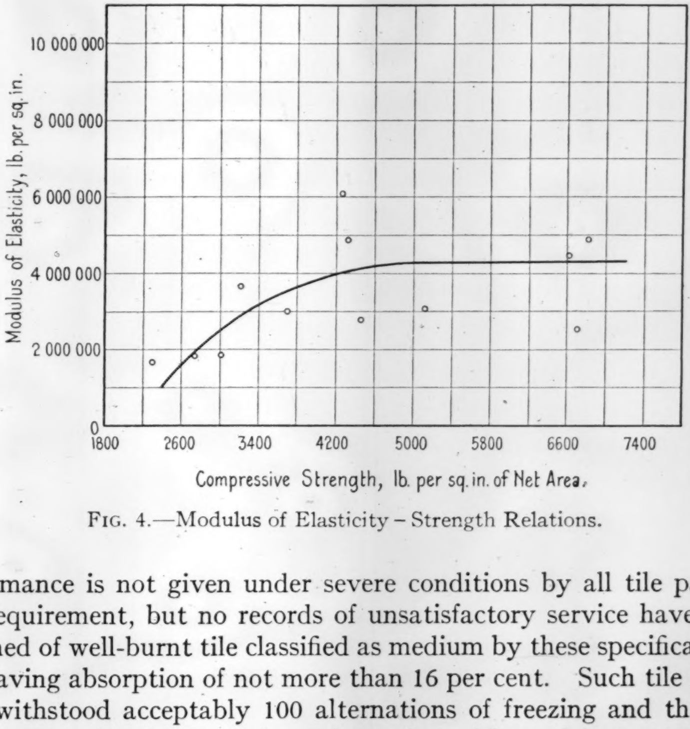

FIG. 4.—Modulus of Elasticity – Strength Relations.

TABLE II.—RESULTS OF FREEZING TESTS.

Specimen	Kind of Clay	Absorption, per cent		Loss after Cycles of Freezing and Thawing, per cent		
		By Immersion	By Boiling	60	90	120
A-1	Shale	7.5	8.9	...	...	...
A-2	Shale	12.8	13.0	0.8	4.9	8.9
A-3	Shale	10.6	13.1	...	...	...
Average of A		10.4	11.7	0.3	1.6	3.0
B-1	Shale	0.8	1.2	...	...	...
B-2	Shale	4.6	4.7	...	...	...
B-3	Shale	11.1	11.3	...	...	...
C-1	Shale	7.6	9.0	...	...	...
C-2	Shale	6.9	9.0	...	...	...
C-3	Shale	7.3	9.1	...	...	...
D-1	Shale	8.9	9.6	...	...	...
D-2	Shale	9.6	10.0	...	...	...
D-3	Shale	11.3	11.8	...	...	...
E-1	Shale	12.6	13.9	...	...	...
E-2	Shale	12.8	13.9	...	...	...
E-3	Shale	12.5	14.3	...	...	...
S-1	Shale	3.4	6.0	...	...	...
S-2	Shale	7.6	8.9	...	...	...
S-3	Shale	9.7	10.4	...	...	0.6
Average of S		6.9	8.4			0.2
F-1	Fire clay	8.8	13.3	...	...	...
F-2	Fire clay	9.8	12.8	...	...	...
F-3	Fire clay	9.5	12.3	...	...	...
H-1	Fire clay	11.2	14.2	...	...	...
H-2	Fire clay	11.4	14.8	...	...	...
H-3	Fire clay	13.3	16.9	3.6	4.4	5.5
Average of H		12.0	15.3	1.2	1.5	1.8
L-1	Fire clay	6.7	9.8	...	...	...
L-2	Fire clay	6.6	8.2	...	...	...
L-3	Fire clay	7.2	9.3	...	...	...
M-1	Fire clay	6.2	9.9	...	...	...
M-2	Fire clay	6.9	9.6	...	...	...
M-3	Fire clay	6.8	9.4	...	...	...
N-1	Fire clay	7.0	11.3	...	...	...
N-2	Fire clay	9.0	13.1	...	...	...
N-3	Fire clay	10.2	12.3	...	...	...
P-1	Fire clay	8.6	13.4	...	...	...
P-2	Fire clay	8.6	12.4	...	...	...
P-3	Fire clay	8.7	13.1	...	...	...
G-1	Fire clay	1.3	6.4	...	...	...
G-2	Fire clay	8.2	10.4	...	...	...
G-3	Fire clay	6.1	9.3	...	...	...
J-1	Surface clay	21.7	...	...	0.4	1.0
J-2	Surface clay	22.5	...	2.0	5.7	13.5
J-3	Surface clay	22.2	...	...	...	6.2
Average of J		22.1		0.7	2.0	6.9
O-1	Surface clay	20.9	22.4	3.9	24.5	29.3
O-2	Surface clay	21.8	23.0	3.0	6.0	taken out
O-3	Surface clay	22.8	24.1	4.2	6.9	22.5
Average of O		21.8	23.2	3.7	12.5	
R-1	Surface clay	9.4	11.1	...	...	...
R-2	Surface clay	10.6	11.5	...	...	...
R-3	Surface clay	10.7	12.1	...	...	...
K-1	Surface clay	10.6	14.4	...	...	...
K-2	Surface clay	14.3	16.6	...	...	...
K-3	Surface clay	15.0	16.5	...	...	...
Q-1	Surface clay	1.9	6.1	...	...	...
Q-2	Surface clay	4.2	4.4	0.2	0.6	0.6
Q-3	Surface clay	13.3	15.2	...	...	...
Average of Q		6.5	8.6	0.1	0.2	0.2

pass this test requirement. There have been instances where underburnt tile graded as hard or medium on absorption and compressive strength has failed in freezing tests and as exposed in cold climates, but such tile should be rejected under the workmanship and finish section of these specifications. There is also considerable evidence that some well-burnt tile grading as soft under the present classification has adequate weathering resistance and provision is made whereby such tile can be accepted by subjection to freezing tests. Such tests are, however, too elaborate to be usable as routine acceptance tests, although they could be made one or more times to establish the properties of the product of a given plant.

(*e*) *Fire Resistance.*—All load-bearing tile should have fire resistance adequate for the conditions under which it is used, the one-hour minimum specified being sufficient for protection against a considerable range of exterior exposures and the less severe general fire conditions in the interior of buildings as used in party and fire walls. Resistance considerably above this limit can generally be obtained and can be raised by increasing the wall thickness.

The tests for fire resistance as for weathering resistance are too elaborate for use as ordinary routine acceptance tests since, to be conclusive, a representative specimen of the construction in which the tile is used must be tested. Provision is therefore made for acceptance based on results of tests already made on the same or closely similar material, leaving it optional with the consumer to make such additional tests as may be considered necessary.

(*f*) *Acceptance.*—In case of failure to meet the absorption and strength requirements, provision is made for a re-test on the remainder of the shipment after inferior material has been taken out. This permits of acceptance of the portion of the shipment that comes up to specifications, which is to the advantage of both producer and consumer, the interest of the latter being generally safeguarded in the contract, as it concerns full delivery and the time allowed for its completion.

Where tile is used under loads considerably below working load values, which is frequently the case, provision is made for acceptance based on weight, absorption, fire resistance, and visual inspection, omitting by agreement the tests for compressive strength. It is believed that acceptable material can be obtained for such purpose in this manner and will enable the specification to be used for a range of work where there otherwise would be no control over the quality of material used.

(*g*) *Sampling.*—Provision is made for sampling each kiln or each

100-ton lot, this being thought to afford good control without an unduly high inspection cost. The values for individual minimums in strength and absorption given in these specifications are based on results from 5 tests of a given lot of tile. Where a larger number of tests is made, a somewhat lower individual minimum is to be expected.

(*h*) *Capping for Compression Tests.*—Studies made at the Bureau of Standards[1] indicate that a 3:1 portland cement-gypsum mixture is a favorable proportion for a capping material, as it concerns workability, time of set, and resulting strength of tile. In the tests, hard end-construction tile, capped with this mixture, gave a strength at 7 days of 90 per cent of that of tile with smoothly ground ends. At 3 days the strength is lower than at 7 days by about 5 per cent. Tile capped with neat gypsum and 3:1 portland cement-gypsum and tested at 1 and 3 hours gave strengths of approximately 88 per cent of that with 3:1 mixture at 7 days; and capped with neat portland cement and aged 10 days, about 93 per cent. With medium or soft tile the influence of the capping on the strength of the tile would probably be somewhat less than with the hard tile used in the tests.

TABLE III.—SATURATION DETERMINATIONS BY FOUR METHODS.

Laboratory Identification	Apparent Porosity				True Porosity by Specific Gravity	Saturation, per cent			
	72-Hour Immersion	1-Hour Boiling	5-Hour Boiling	Vacuum Treatment		72-Hour Immersion	1-Hour Boiling	5-Hour Boiling	Vacuum Treatment
K.......	24.0	28.6	30.2	31.0	31.2	77.1	91.3	96.7	99.4
L.......	13.5	18.4	19.2	21.5	22.6	59.9	81.3	85.0	95.1
M.......	17.6	19.3	19.9	21.4	22.6	78.3	85.5	88.4	95.0
N.......	16.1	22.6	23.7	25.2	26.7	60.3	84.7	88.8	94.3
O.......	36.3	36.9	38.8	39.5	40.0	90.9	92.5	97.0	99.0
P.......	18.7	25.5	26.5	27.4	27.9	66.9	91.7	96.7	98.1
Q.......	16.5	20.4	21.4	21.8	22.5	73.2	90.5	95.0	96.7
R.......	20.1	22.5	23.2	24.3	24.7	81.3	91.2	94.0	98.4
Average.	20.4	24.4	25.3	26.5	27.3	73.5	88.6	92.7	97.0

(*i*) *Methods of Making the Absorption Test.*—The results of an investigation[2] made at the Bureau of Standards to determine the effectiveness of different methods of making absorption determinations indicate that for specimens of the structure and thickness of hollow tile shells and webs the one-hour boiling as prescribed in the specifications will give the same absorption within one per cent as the 5-hour boiling treatment. Some general results reduced to percentage porosity and saturation are given in Table III. The vacuum treatment, while giving the nearest approach to full saturation, requires equipment that is not generally available where acceptance tests are made. The one-hour boiling test is convenient in that it can be completed in one day and can be made with improvised equipment if necessary. If sufficiently large specimens are taken, commercial scales can be used where laboratory equipment is not available.

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[1] *Journal*, American Ceramic Society, Vol. 6, No. 5, May, 1923.

[2] *Journal*, American Ceramic Society, Vol. 5, No. 11, November, 1922.

(*j*) *Freezing Tests.*—In conducting the freezing test it is important to continue the freezing to the point where all portions of the specimens are below freezing temperature. It is usually desirable to maintain a temperature in the chamber of not less than 10° C. below zero; but the temperature of the chamber cannot be taken as a criterion of the temperature of the interior of the specimens, since the progress of the freezing process into the material is slow on account of the liberation of latent heat. It was found necessary to maintain temperatures below freezing for not less than 4 hours to insure penetration throughout the charge. Thawing in water at room temperature can usually be accomplished in one hour.

The initial weighings and weighings for loss must be made on the dry specimens, since weighings for loss in the saturated condition are subject to error because of the gradually increasing absorption of the specimens, which would mask minor losses. Errors due to this cause may be as high as one per cent, depending on the completeness of the initial saturation and the structure of the tile material.

NO. 3. *Proposed Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition, and Furring Tile.*—These specifications[1] in outline and requirements are similar to those for load-bearing tile except that the strength requirements are based on the net area, the object being to establish classification in point of hardness of the material rather than to secure a definite amount of load-carrying capacity for the unit as a whole. The necessary strength, bearing area, and insulation for non-bearing purposes are deemed secured by the minimum weight requirements.

For room partitions in which wooden frames, doors, trim, and plain glass are used, no requirement for fire resistance may be necessary. Otherwise the fire-resistance requirement is placed on the same basis as for load-bearing tile.

No weathering requirement is included, as fireproofing, partition and furring tile are not designed for exterior work.

NO. 4. *Proposed Tentative Specifications and Tests for Hollow Burned-Clay Floor Tile.*—These specifications[2] also conform to the outline of that for load-bearing wall tile except that the strength requirement is based on net area and no requirement is included for weathering resistance.

The committee appreciates that it would have been more logical to place strength on the gross-area basis, but on account of the great variety in form of tile used in floors it did not appear feasible to bring them to a common standard on the basis of gross-area strength. Since the unit loads imposed on tile construction in floors is generally not high, it was deemed that the necessary strength can be secured through the net area strength and the weight requirements.

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[1] See p. 824.—ED.

[2] See p. 829.—ED.

The chairman desires to commend the active interest taken by the committee members in the work of the committee, without which what has been accomplished would not have been possible. Acknowledgement is due to H. D. Foster for assistance in preparing the test data included in this report.

The following is the result of the letter ballot vote of the committee on the recommendations contained in this report:

Items	Affirmative	Negative	Not Voting
I. REVISED TENTATIVE STANDARD RECOMMENDED FOR ADOPTION AS STANDARD			
Tentative Definitions of Terms Relating to Hollow Tile (C 43 – 23 T)	19	0	1
II. PROPOSED REVISIONS OF EXISTING TENTATIVE STANDARD			
Tentative Specifications for Clay Hollow Building Tile (C 34 – 21 T)	19	0	1
III. PROPOSED NEW TENTATIVE STANDARDS			
Proposed Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition, and Furring Tile	19	0	1
Proposed Tentative Specifications and Tests for Hollow Burned-Clay Floor Tile	19	0	1

This report has been submitted to letter ballot of the committee, which consists of 20 members, of whom 19 have voted affirmatively, none negatively, and one has refrained from voting.

Respectfully submitted on behalf of the committee,

S. H. INGBERG,
Chairman.

F. J. HUSE,
Secretary.

EDITORIAL NOTE

The Tentative Definitions of Terms Relating to Hollow Tile, revised as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The definitions, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Clay Hollow Building Tile were accepted as recommended in this report. The tentative specifications, as thus revised, appear on page 818.

The proposed Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile and for Hollow Burned-Clay Floor Tile, referred to in this report, the latter specifications amended as given on page 26 of the Summary of Proceedings, were accepted for publication as tentative and appear on pages 824-833.

REPORT OF COMMITTEE C-11
ON
GYPSUM

Committee C-11 is adhering to its policy of holding not less than three meetings each year. During the past year, these meetings were held at Washington, D. C., on October 23 and 24, 1923, at Chicago, Ill., on April 10 and 11, 1924, and at Atlantic City, N. J., in conjunction with the June, 1924, meeting of the Society.

The year's work has been singularly productive in the development of information of particular value to the producer and consumer. Considerable research work has been necessary, most of the information needed being supplied from test data developed at the U. S. Bureau of Standards.

The following are the recommendations to the Society, relative to the specifications under the jurisdiction of Committee C-11:

Tentative Specifications for Gypsum (*C 22 - 23 T*).[1]—The committee has agreed upon sizes which will properly govern crushed and ground gypsum, and a new requirement for sized gypsum has been introduced. It was agreed that all reference to screens or sieves should be worded in accordance with the U. S. Bureau of Standards' Standard Sieve Series and a footnote to this effect be included. Also the word "marketed" was omitted where it occurs, and other wording was changed. As revised, Section 3 will now read as follows:

"3. Gypsum may be in any of the following forms and sizes:

"(*a*) *Run-of-Mine Gypsum.*—The form in which it comes from the mine or quarry.

"(*b*) *Crushed Gypsum.*—Run-of-mine gypsum further reduced so that all of it will pass a 3-in. (76-mm.) ring, and not more than 25 per cent shall pass a No. 100 sieve.

"(*c*) *Sized Gypsum.*—Shall all pass a 1½-in. (38-mm.) ring, and not more than 10 per cent shall pass a ¼-in. sieve.

"(*d*) *Ground Gypsum.*—Gypsum further reduced for specific uses. Ground gypsum may be in any of the following standard forms:

No. 1.—This material shall all pass a No. 14 sieve, and not less than 85 per cent of it shall pass a No. 100 sieve.

No. 2.—This material shall all pass a No. 14 sieve, and not less than 60 nor more than 85 per cent of it shall pass a No. 100 sieve.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 629 (1923).

No. 3.—This material shall all pass a No. 8 sieve, and not less than 40 nor more than 60 per cent of it shall pass a No. 100 sieve.

No. 4.—This material shall all pass a No. 100 sieve.

NOTE.—All sieve numbers refer to U. S. Bureau of Standards' Standard Sieve Series."

At a meeting of the committee held in Chicago, Ill., on April 11, it was recommended that these tentative specifications, as revised, be advanced to standard. A reconsideration of this matter by the Committee at the meeting of June 24 indicated the advisability of continuing these specifications as tentative, and the committee therefore makes this its recommendation.

Standard Specifications for Calcined Gypsum (*C 23 - 22*).[1]—It is respectfully recommended that these specifications be submitted to the American Engineering Standards Committee for consideration as American standard, after omitting the footnote reading as follows:

"Specifications for the color and plasticity of calcined gypsum will be supplied when the information is available."

Standard Specifications for Gypsum Plasters (*C 28 - 21*).—At the last meeting of the Society it was recommended that these specifications be submitted to the American Engineering Standards Committee for consideration as American standard, after omitting the Editorial Note at the end which refers to color specifications.

The committee is now endeavoring to develop specifications for Casting, Molding, Pottery, Dental and Orthopedic plasters, as well as information on the acoustic properties of plastered panels. The Bureau of Standards is now conducting the necessary sound test determinations.

Tentative Specifications for Gypsum Plastering Sand (*C 35 - 21 T*).[2]—The committee has made an effort to reconcile these tentative specifications as closely as possible to the definition of sand as proposed by Committee E-8 on Nomenclature and Definitions. The specifications were therefore entirely revised to read as follows:

"*Definition*.—Sand used for plastering purposes, in which a gypsum plaster is employed, shall be the fine granular material naturally or artificially produced by the disintegration of rock containing not less than 80 per cent by weight of fine silica, feldspar, dolomite or calcite.

"*Composition*.—(*a*) It shall be free from salt and from alkaline, organic or other deleterious substances.

"(*b*) It shall be graded from fine to coarse, and when dry, not more than 10 per cent by weight shall be retained on a No. 8 sieve; not less than 80 per cent by weight shall be retained on a No. 50 sieve; and not more than 6 per cent by weight shall pass a No. 100 sieve. These sieves shall meet the specifications given in the U. S. Bureau of Standards' Standard Sieve Series."

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[1] A.S.T.M. Standards Adopted in 1922.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 559 (1921).

The committee held some discussion as to the necessity for limiting the coarse particles constituting the 10 per cent permitted to be retained upon a No. 8 sieve. This matter has not been decided and for this reason it is recommended that these specifications, as amended, be continued as tentative for another year.

The letter ballot of the committee on this recommendation is as follows: Affirmative, 22; negative, 0; not voting, 11.

Tentative Specifications for Gypsum Wall Board (C 36 - 22 T).[1]—These specifications state that the lengths of gypsum wall board shall be 4, 5, 6, 7, 8 or 10 ft. This product is now manufactured in varying lengths up to 12 ft. Also, further consideration should be given to desired tolerance limitations on dimensions, with particular reference to thickness, and the possible elimination of weight specifications in favor of placing gypsum boards upon a required performance basis. It is therefore recommended that these specifications be continued as tentative, changing Section 4 (*c*) to read as follows:

> "The lengths shall be from 4 ft. (1.22 meter) to 12 ft. (3.66 meter) inclusive, except that a tolerance of $\frac{3}{8}$ in. (9.5 mm.) from the length of individual boards is permissible. Special boards may be cut to any desired length within the limits prescribed."

Tentative Specifications for Gypsum Plaster Board (C 37 - 22 T).—For somewhat similar reasons offered in the case of the specifications for gypsum wall board, it is recommended that these specifications be continued as tentative pending contemplated revision.

Tentative Specifications for Gypsum Partition Tile or Block (C 52 - 23 T).[2]—The amendments to these specifications were such as to practically consist of a new set of tentative specifications. These new specifications are appended hereto,[3] and it is recommended that they be accepted as tentative to replace the present specifications. The letter ballot of the committee on this recommendation is as follows: Affirmative, 22; negative, 0; not voting, 11.

Standard Methods of Testing Gypsum and Gypsum Products (C 26 - 23).—The committee has under consideration substituting another type of machine for measuring consistency in place of the Southard Viscosimeter which is now specified in these standard methods. There is also the possibility of adding, as alternative, other methods for the preparation of the sample and the determination of combined water in gypsum. Also, there is in course of preparation laboratory and field methods for testing the strength of gypsum tile, gypsum wall and plaster board.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 710 (1922).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 632 (1923).

[3] See p. 840.—ED.

Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 - 23 T).[1]—The committee has considered the recommendations of Committee E-8 on Nomenclature and Definitions on these definitions and has found it necessary to make certain slight corrections and rewording in each of the twelve tentatively adopted terms. A new definition has been added, and five additional terms, which had been reworded by Committee E-8 have been adopted with but slight change. It is recommended that these eighteen definitions, as finally amended, and as appended hereto,[2] be referred to Committee E-8 for approval, prior to their advancement to standard. The letter ballot of the committee on this recommendation is as follows: Affirmative, 22; negative, 2; not voting, 9.

The committee has not lost sight of the value, to producer and consumer, of information about the materials coming under its jurisdiction. As a result of this desire to promote the knowledge of gypsum commodities, the necessary assistance is being rendered by the Bureau of Standards which is carrying forward exhaustive tests involving the acoustic and fire-resisting properties of gypsum plasters and materials.

Some tests on gypsum partition tile are reported in a paper being presented at this annual meeting by J. M. Porter, entitled "Properties of Gypsum Tile."[3]

This report has been submitted to letter ballot of the committee, which consists of 33 members, of whom 23 have voted affirmatively, none negatively, and 10 have refrained from voting.

Respectfully submitted on behalf of the committee,

WARREN E. EMLEY,
Chairman.

V. G. MARANI,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Tentative Specifications for Gypsum, for Gypsum Plastering Sand, for Gypsum Wall Board, for Gypsum Partition Tile or Block and of the Tentative Definitions of Terms Relating to the Gypsum Industry were accepted for publication as tentative, as recommended in this report, with the exceptions given on page 25 of the Summary of Proceedings. The tentative standards, as thus revised, appear on pages 834-843 and 849 respectively.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 642 (1923).

[2] See p. 849.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

REPORT OF COMMITTEE D-1
ON
PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS

Committee D-1 on Preservative Coatings for Structural Materials has held two meetings during the past year. At the meeting held in Philadelphia on October 2, 1923, about thirty members were present. On April 25, 1924, the second meeting was held in Washington, D.C., this date being chosen because of the fact that the general meeting of the American Chemical Society was also held during that week in Washington. The number in attendance at the April meeting was sixty.

During the past year, the committee has shown a healthy growth, and the work accomplished by the sub-committees has been much greater than during the past few years. A new Sub-Committee on Shellac has been formed and the personnel of several other sub-committees has been somewhat changed.

Sub-Committee V on Linseed Oil has carried out a great deal of cooperative experimental work, but has not as yet proposed any standard recommendations.

Sub-Committee VI has recommended the withdrawal of definitions for "bulk" and "voids" and has suggested a slight change in the standard definition for "fineness".

Sub-Committee VIII has recommended tentative methods of routine analysis of titanium pigments and a tentative method of test for coarse particles in paint pigments, and is also recommending the advancement to standard of the Tentative Method of Test for Specific Gravity of Pigments (D 153 - 23 T).

Sub-Committee IX has recommended tentative methods of testing varnish and has recommended that the Tentative Methods of Testing Oleo-Resinous Varnishes (D 154 - 23 T) be advanced to standard.

Sub-Committee XII has recommended that the tentative specifications for turpentine be advanced to standard.

Sub-Committee XIII reports a large amount of experimental work on shellac and its analysis It recommends the advancement to standard of the Tentative Methods of Testing Shellac (D 29 - 23 T) to supersede the present standard methods. It further recommends the publication as tentative of a method of test for determination of wax in shellac.

Sub-Committee XIV has reported another inspection of the Altoona panels.

Sub-Committee XV has recommended that with slight revision, the Tentative Specifications for Zinc Oxide, Leaded Zinc Oxide, Basic Carbonate White Lead, Basic Sulfate White Lead, Red Lead, and Ocher be advanced to standard. It has suggested that the present Tentative Specifications for Iron Oxide be revised and continued as tentative. Specifications for lithopone, lampblack, bone black, chrome yellow and chrome green were proposed for consideration, but not for approval as either tentative or standard.

Sub-Committee XXIII reports the results of a large number of tests on ship bottoms, including U. S. Navy vessels, shipping board vessels and privately owned vessels. No recommendations, however, are made.

Details of the work of the sub-committees are contained in the individual reports which are a part of this report.

These have been submitted to a letter ballot of the committee, which consists of 147 members, from whom 60 replies were received. The vote taken on each section of the report is as follows:

Item	Affirmative	Negative	Not Voting
Report of Sub-Committee III on Testing of Paint Vehicles	51	0	9
Report of Sub-Committee V on Linseed Oil	50	0	10
Report of Sub-Committee VI on Definitions of Terms used in Paint Specifications, including: Withdrawal of standard definition for "bulk"	50	0	10
Withdrawal of standard definition for "voids"	50	0	10
Revision of standard definition for "fineness"	49	0	11
Report of Sub-Committee VIII on Methods of Analysis of Paint Materials, including: Tentative Methods of Routine Analysis of Titanium Pigments	47	0	13
Tentative Method of Test for Coarse Particles in Paint Pigments	44	1	15
Advancement to Standard of the Tentative Method of Test for Specific Gravity of Pigments (D 153 - 23 T)	53	1	3
Report of Sub-Committee IX on Varnish, including: Advancement of Tentative Methods of Testing Oleo-Resinous Varnishes (D 154 - 23 T) to standard	41	1	18
Tentative Methods of Testing Oleo-Resinous Varnishes	40	1	19
Report of Sub-Committee XII on Turpentine, including Advancement of Tentative Specifications for Turpentine (D 13 - 21 T) to standard	49	1	10
Report of Sub-Committee XIII on Shellac	46	0	14
Report of Sub-Committee XIV on Preparation of Iron and Steel Surfaces for Painting	41	0	19
Report of Sub-Committee XV on Pigments, Dry and in Oil, when Marketed in that Form, including: Revision and advancement to standard of Tentative Specifications for:			
Zinc Oxide (D 79 - 21 T)	50	0	10
Leaded Zinc Oxide (D 80 - 21 T)	47	0	13
Basic Carbonate White Lead (D 81 - 21 T)	47	1	12
Basic Sulfate White Lead (D 82 - 21 T)	48	1	11
Red-Lead (D 83 - 21 T)	48	0	12
Ocher (D 85 - 21 T)	48	1	11
Revision of Tentative Specifications for Iron Oxide and Iron Hydroxide (D 84 - 21 T)	46	0	14
Report of Sub-Committee XXIII on Anti-Fouling Paints	42	0	18

This report has been submitted to letter ballot of the committee, which consists of 147 members, of whom 60 have voted affirmatively, none negatively and 87 have refrained from voting.

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

R. L. HALLETT,
Secretary.

Editorial Note

The revisions of the Standard Definitions of Terms Relating to Paint Materials, recommended in this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The definitions, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Methods of Testing Shellac, proposed in 1923, and amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Specifications for Turpentine and the Tentative Method of Test for Specific Gravity of Pigments were approved at the annual meeting, as recommended in this report, and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The standards appear in the 1924 Book of A.S.T.M. Standards. The Tentative Specifications for Zinc Oxide, for Leaded Zinc Oxide, for Basic Carbonate White Lead, for Basic Sulfate White Lead, for Red Lead and for Ocher and the Tentative Methods of Testing Oleo-Resinous Varnishes, amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The standards, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed Tentative Method of Test for the Determination of Wax in Shellac, the proposed Tentative Methods of Testing Oleo-Resinous Varnishes, the proposed Tentative Methods of Routine Analysis of Titanium Pigments and the proposed Method of Test for Coarse Particles in Paint Pigments were accepted for publication as tentative and appear on pages 854–863. The proposed revisions of the Tentative Specifications for Iron Oxide and Iron Hydroxide were accepted. The tentative specifications, as thus revised, appear on page 852.

The withdrawal of the Standard Specifications for Purity of Raw Tung Oil, recommended by the committee, was approved.

REPORT OF SUB-COMMITTEE III ON TESTING OF PAINT VEHICLES

There were forwarded to some members of the sub-committee, who stated that they would have time for analytical work, two samples of tung oil obtained late in the spring. Sample No. 1 was pressed in an Anderson expeller from tung oil nuts with the shells on, obtained in the spring of 1924. Sample No. 2 was pressed in March, 1922, from Florida nuts of the 1921 crop, an Anderson expeller being used. The oil, however, was stored in a can with a very large air space so that some oxidation may have taken place during the period of two years from the time of crushing to the time of examination.

The reports of the analysts are presented in Table I. It will be noted that the iodine number of the sample that was stored for a long period of time in a partially filled can has dropped a few points below that of normal fresh oil.

Special attention is drawn to the very light color of the oils and the very low period of time required for polymerization, as determined by the two different heat tests applied. These properties make the American grown oil exceptionally attractive.

Pending further work on a number of samples of oil, that the committee expects to carry on during this year, it is recommended that the present Tentative Specifications for Raw Tung Oil (D 12 – 23 T) remain tentative and that the present Standard Specifications for Purity of Raw Tung Oil (D 12 – 16)[1] be withdrawn.

H. A. GARDNER,
Chairman.

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[1] 1921 Book of A.S.T.M. Standards.

TABLE I.—RESULTS ON TWO SAMPLES AMERICAN TUNG OIL.

Observer	Appearance and Color	Specific Gravity, 15.5°/15.5°C.	Refractive Index	Acid Value	Saponification Number	Unsaponifiable Matter, per cent	Iodine Value	Heat Test, Browne Method, min.	Quality Test, Worstall Method
SAMPLE NO. 1									
White and Stem	Exceptionally pale	0.942	.....	0.57	194	....	164	10	....
Kenney (Central Testing Laboratory, City of N. Y.)	....	0.9418	1.4987 (?)	0.56	195.1	0.55	166	....	$6\frac{3}{4}$ Pale, firm, dull and dry like dry bread.
Trevithick (Bur. of Chem., N. Y. Produce Exchange)	....	0.941	1.5202	0.5	194.4	0.38	169.5	....	....
Sward (U. S. Bur. Standards)	....	0.9414	1.5190	0.7	192.1	0.58	166.5	$10\frac{3}{4}$ Pale, firm, dry, crumbly	....
Parks.........	Extremely pale and clear	......	......	....	.....	....	.....	....	$6\frac{1}{4}$ Very dry.
Worstall......	....	......	......	....	.....	....	.....	....	6 (15 seconds to gel.) Extremelypale, very dry and firm.
SAMPLE NO. 2									
White and Stem	Exceptionally pale	0.944	......	1.0	194	....	159	$9\frac{3}{4}$	....
Kenney (Central Testing Laboratory, City of N. Y.)	....	0.9444	1.4985 (?)	1.0	193.2	0.52	160.9	....	$6\frac{1}{3}$ Pale, granular, and soft. Dull and tacky.
Trevithick (Bur. of Chem., N. Y. Produce Exchange)	....	0.9437	1.5179	0.9	195.7	0.61	163.1	....	....
Sward (U. S. Bur. of Standards)	....	0.9436	1.5169	1.1	194.6	0.6	160.8	$9\frac{5}{8}$ Firm, dry, crumbly.	....
Parks.........	Extremely pale and clear	......	......	....	.....	....	.....	....	$5\frac{1}{2}$ Very dry
Worstall......	....	......	......	....	.....	....	.....	....	$5\frac{3}{4}$ (15 sec. to gel.) Very pale, very dry and firm.

REPORT OF SUB-COMMITTEE V ON LINSEED OIL

SUMMARY AND CONCLUSIONS

In planning the work outlined in this report, this sub-committee had as its object compliance with the resolution passed by Committee D-1 requesting Sub-Committee V to prepare specifications for linseed oil covering both purity and quality. The principal problems before the committee were (1) the establishment of standards for iodine number by the Wijs method and (2) the development or application of a satisfactory method of test which would serve to bar out any oil which would have a tendency to deposit an excessive amount of settlings or foots.

In pursuance of this plan, there were distributed to members of the committee a series of samples of linseed oil which are described later in this report. These oils were selected to represent linseed oil which had been subjected to various temperature conditions to which a commercial shipment of linseed oil might be subjected. The analysts were requested to make iodine number determinations by the Hanus method and by the Wijs method. They were also requested to make foots determinations by the Walker-Wertz method, which is the present A.S.T.M. method as prescribed in the Tentative Specification for Foots Permissible in Properly Clarified Pure Raw Linseed Oil from North American Seed (D 51 – 18 T). Determinations were also to be made on the samples after various chilling and heating treatments.

The committee members reporting upon these samples were as follows:

	MEMBER	REPRESENTED BY	ASSISTED BY
No. 1	Congoleum Company, Inc.	R. D. Bonney	K. A. Horn
No. 2	F. A. Hull		
No. 3	Southern Cotton Oil Co.	H. S. Bailey	H. P. Strack
No. 4	E. I. du Pont de Nemours and Co.	J. Eliot Booge	
No. 5	C. B. Mills		R. L. Hallett and G. W. Thompson
No. 6	D. A. Kohr		E. W. Fasig, Mr. Marling and Mr. Wade
No. 7	The Standard Textile Products Co.	J. B. Davis	George Cramer
No. 8	L. L. Steele		
No. 9	Pittsburgh Plate Glass Co., Patton-Pitcairn Division	P. R. Croll	

The comparisons of the Wijs and Hanus methods indicated that there was little to choose between the two methods from the standpoint of accuracy. In general, the concordance between the various operators was very good by either method. One of the operators had results much higher than those of the others by the Wijs method, while another reported figures by the Hanus method which were somewhat lower than the rest. See Tables I, II, and III. The subcommittee believes that the use of the Wijs method is advisable because of its greater applicability. It is either possible to substitute the proper limits for the iodine number when determined by the Wijs method or to include limits for both Wijs and Hanus method, thus allowing a choice between them. Taking into account results reported by this committee in 1921[1] and the results reported in this instance, the average of 5 units should be added to the limits as set by the Hanus method to establish those for the Wijs method.

The committee and many of the individual members devoted a great deal of time to the matter of a satisfactory foots test. Nine different operators reported results on the samples which were tested for foots by the method of Tentative Specifications D 51 – 18 T. These results are here reported in Tables I and IV. The results obtained are very similar to those obtained in previous years, and there is the same lack of concordance that has always existed when this test has been applied to the same oil by different operators. There is also the same lack of concordance that has always existed when the same oil has been tested by the same operator after having been subjected to varying conditions which it might meet in commercial practice, principally temperature variations. A variation of the method by heating the oil improves the concordance slightly, but not sufficiently. The variables involved in the method seem to be too great to allow of satisfactory results. The figures speak for themselves. The sub-committee, therefore, must reluctantly reaffirm the position taken in its last year's report, namely, that neither this test, nor any modification of it proposed to date is sufficiently accurate for use in standard specifications.

As the results began to make clear the fact that some other method must be sought for, certain members of the committee set to work to develop other methods which might give satisfactory results in quantitatively estimating sediment-forming qualities of any linseed oil. The conclusions of some of these committee members from a study of the problem were somewhat as follows: The foots content of linseed oil appears to consist primarily of three elements: (1)

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 334 (1921).

moisture; (2) high-melting-point saturated fats which solidify at, or slightly below, normal temperature; (3) mucilaginous material which is held largely in suspension and colloidal solution in the oil. This albuminous material appears to be identical with the substance form-

TABLE I.

Laboratory	Foots, per cent				Iodine Number		Difference
	Foots, as Received	Heated to 150° F.	Chilled to 32° F.	Chilled and Heated	Hanus	Wijs	
OIL No. 56							
No. 1. Bonney	1.4	1.4	2.4	1.4	178.4	183.5	5.1
No. 2 Hull	1.2	0.6	1.4	0.4	175.8	183.4	7.6
No. 3. Bailey	2.	6.	1.0	4.6	177.7	183.62	5.92
No. 4. Booge	2.56	1.96	1.6	1.2	171.1	182.5	11.4
No. 5. Thompson	1.10	0.5	1.7	1.0	177.8	182.7	4.9
No. 6. Fasig	0.7	0.7	1.8	2.4	177.3	182.1	4.8
No. 7. Davis	1.0	0.4	1.2	0.8	178.5	181.3	2.8
No. 8. Steele	1.4	0.8	1.4	1.0	179.3	181.5	2.2
No. 9. Croll	2.0	2.0	2.0	2.0	174.	......	....
Average	1.48	1.57	1.6	1.6	176.64	182.57	5.9
High	2.56	6.	2.4	4.6	179.3	183.62	11.4
Low	0.7	0.4	1.	0.4	171.1	181.3	2.2
Difference	1.86	5.6	1.4	4.2	8.2	2.32	9.2
Difference between High and Average	1.08	4.43	0.8	3.	2.66	1.05	5.5
Difference between Low and Average	0.78	1.17	0.6	1.2	5.54	1.27	3.7
OIL No. 57							
No. 1. Bonney	3.2	1.2	3.4	1.6	179.1	183.7	4.6
No. 2. Hull	3.2	0.6	2.8	0.68	175.4	184.8	9.4
No. 3. Bailey	4.6	4.8	3.	5.4	177.23	183.22	5.99
No. 4. Booge	4.	2.08	2.32	1.6	172.8	181.4	8.6
No. 5. Thompson	3.2	0.7	3.80	1.2	178.1	182.5	4.4
No. 6. Fasig	4.9	0.9	4.8	2.7	177.4	181.5	4.1
No. 7. Davis	2.4	0.6	2.8	1.6	179.7	181.5	1.8
No. 8. Steele	2.5	1.1	2.6	1.2	179.3	181.4	2.1
No. 9. Croll	3.2	1.6	4.8	1.6	173.5	......	....
Average	3.46	1.5	3.37	1.95	176.85	182.50	5.65
High	4.9	4.8	4.8	5.4	179.7	184.8	9.4
Low	2.4	0.6	2.32	0.68	172.8	181.4	1.8
Difference	2.5	4.2	2.48	4.72	6.9	3.4	7.6
Difference between High and Average	1.44	3.3	1.43	3.45	2.85	2.30	3.75
Difference between Low and Average	1.06	0.9	1.05	1.27	4.05	1.10	3.85
OIL No. 58							
No. 1. Bonney	2.0	1.8	3.6	2.2	178.3	183.3	5.
No. 2. Hull	2.8	1.6	2.6	2.4	177.5	183.8	6.3
No. 3. Bailey	5.8	7.6	4.4	7.	176.42	183.65	7.23
No. 4. Booge	2.2	1.52	2.6	2.68	171.9	182.8	10.9
No. 5. Thompson	3.8	2.6	4.	2.6	178.1	182.5	4.4
No. 6. Fasig	1.8	0.9	3.4	2.7	177.1	181.4	4.3
No. 7. Davis	3.2	2.4	2.4	2.4	177.6	181.3	3.7
No. 8. Steele	2.4	2.7	2.6	2.5	178.5	180.7	2.2
No. 9. Croll	3.2	2.0	2.0	1.6	174.	......	....
Average	3.02	2.57	3.07	2.89	176.60	182.43	5.83
High	5.8	7.6	4.4	7.0	178.5	183.65	10.9
Low	1.8	0.9	2.	1.6	171.9	180.7	2.2
Difference	4.0	6.7	2.4	5.4	6.6	2.95	8.7
Difference between High and Average	2.78	5.03	1.33	4.11	1.90	1.22	5.07
Difference between Low and Average	1.22	1.67	1.07	1.29	4.70	1.73	3.63

TABLE I. (*Continued*)

Laboratory	Foots, per cent				Iodine Number		Difference
	Foots, as Received	Heated to 150° F.	Chilled to 32° F.	Chilled and Heated	Hanus	Wijs	
OIL No. 59							
No. 1. Bonney	5.6	2.2	3.8	2.4	178.6	183.2	4.6
No. 2. Hull	3.0	2.4	2.2	2.4	179.72	183.7	3.98
No. 3. Bailey	5.2	11.2	4.4	6.4	175.23	183.4	8.17
No. 4. Booge	2.76	1.6	2.8	2.8	171.2	181.6	10.4
No. 5. Thompson	4.8	3.0	4.8	3.0	177.8	182.3	4.5
No. 6. Fasig	2.8	1.1	3.2	1.8	176.5	181.2	4.7
No. 7. Davis	6.8	2.0	4.0	2.5	177.9	181.2	3.3
No. 8. Steele	2.6	2.5	3.0	3.0	178.5	181.1	2.6
No. 9. Croll	4.0	2.8	3.6	2.4	174.5	......	....
Average	4.17	3.2	3.5	3.00	176.7	182.21	5.51
High	6.8	11.2	4.8	6.4	179.72	183.7	10.4
Low	2.6	1.1	2.2	1.8	171.2	181.1	2.6
Difference	4.2	10.1	2.6	4.6	8.52	2.6	7.8
Difference between High and Average	2.63	8.0	1.3	3.40	3.02	1.49	4.89
Difference between Low and Average	1.57	2.1	1.3	1.2	5.5	1.11	2.91

ing the "break" when a linseed oil is heated. The first constituent, moisture, is not indicated by our present tentative method for foots, but it can easily be determined quantitatively by any of several standard procedures. The high-melting-point fats are one of the greatest difficulties in the way of any of the methods proposed to date. Temperature and moisture conditions affect, to a very large degree, the amount of these solidifiable fats which are detected by any of our proposed foots tests. This effect is so great that it makes these proposed foots tests, in general, quite unreliable. The mucilaginous material probably constitutes the most serious and undesirable portion of the foots in commercial linseed oil. This material appears to be identical with the "break" which can be separated from the linseed oil and quantitatively determined.

In view of the above, it was determined to attempt the estimation of the break, or non-fatty portion, of the foots separately. Various volumetric measurements were tried, but none were entirely satisfactory. A gravimetric method was finally evolved which showed the amount of break as a definite percentage by weight. The principle of this method was suggested by J. B. Davis and was later considerably modified by R. D. Bonney and K. A. Horn. The principle of the method consisted in heating a portion of the oil to about 550° F. (290° C.) with the addition of hydrochloric acid. This treatment separates into a flocculent form the mucilaginous material constituting the break. The oil is then diluted with a solvent, collected on a weighed filter, washed free of oil and weighed. The results can be expressed directly as percentage by weight of break, which is believed to be the potential source of the mucilaginous material in the foots. Determinations made by five members of the committee, using this method, are reported in Tables V and VI. The concordance obtained by this method is not excellent, but it shows a considerably greater accuracy than the Walker-Wertz method for foots. The results indicate possibilities of the final development of an accurate quality determining test. The method is recommended for consideration and trial, and suggestions are solicited. The sub-committee will arrange for further cooperative work on it during the year.

TABLE II.—AVERAGES OF IODINE NUMBER DETERMINATIONS OF LINSEED OIL.

Method Used	Sample No. 56	Sample No. 57	Sample No. 58	Sample No. 59	Average
Wijs (all results)	182.6	182.5	182.4	182.2	182.4
Hanus A, including all results reported	176.6	176.9	176.6	176.7	176.7
Hanus B, excluding Analyst No. 4	177.8	178.0	177.6	177.8	177.8
Difference A, Wijs minus Hanus A	6.0	5.6	5.8	5.5	5.7
Difference B, Wijs minus Hanus B	4.8	4.5	4.8	4.4	4.6

TABLE III.—MAXIMUM VARIATIONS OF DETERMINATIONS OF IODINE NUMBER OF LINSEED OIL BY WIJS AND HANUS METHODS.

Sample	Variation—Highest to Lowest		
	Wijs (All Results)	Hanus (All Results)	Hanus (Excluding No. 4)[a]
No. 56	2.3	8.2	5.3
No. 57	3.4	6.9	6.2
No. 58	3.1	6.6	4.5
No. 59	2.6	8.7	5.4
Average	2.9	7.6	5.4

Maximum Variation (all samples by all operators) by Wijs Method: 180.7 to 184.8, or 4.1; by Hanus Method: 171.1 to 179.9, or 8.8.

[a] Results shown are for Hanus Method excluding figures reported by Analyst No. 4.

Maximum Variation on all samples and by all operators excepting No. 4 (by Hanus Method) was: 173.5 to 179.9, or 6.4.

In view of the fact that the break, or mucilaginous portion of the foots, contains a very high percentage of ash,[1] it recently occurred to Bonney and Horn that an ash determination might be developed as a measure of this portion of the foots. In the past few weeks they have made a number of determinations of ash on various oils, as well as on the break from these oils. These determinations indicate that in a raw linseed oil a very large proportion of the ash is contained in the break or foots, and also that the break or foots (barring fats) appear to always contain a high percentage of ash. It appears, from the work that has been done to date, that a specification for the maximum ash allowable in a raw linseed oil may possibly prove to satisfactorily limit the foots or potential foots. Table VII gives the results which were obtained upon several oils by this method. The committee proposes to undertake further work with this method which has the advantages of simplicity and rapidity, and which would give duplicable results in the hands of different operators.

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[1] G. W. Thompson, "The Composition of the Break from Linseed Oil," *Journal*, Am. Chemical Soc., July, 1903.

There is some question as to whether it is desirable to have a specification for solidifiable fats in raw linseed oil. It is true that solidifiable fats form a considerable proportion of the foots of an oil under certain temperature conditions, but, as these fats are a constituent part of linseed oil itself, the determination of their presence and amount should perhaps be left to specifications for a refined oil rather than for a raw linseed oil. The mucilaginous material appears to be the principal thing which we wish to quantitatively determine. It is of interest to note, however, that J. B. Davis has been working upon a method of separating the solidifiable fats by refrigerating and centrifuging in an apparatus thermostatically maintained at a low temperature.

TABLE IV.—VARIATIONS IN FOOTS DETERMINATIONS OF LINSEED OIL.

Sample		Percentage of Foots by Volume				
		Average	Minimum	Maximum	Variation	Percentage Variation
Nos. 56 and 57	Heated Samples	1.3	0.4	2.7	2.3	177
	All Samples (As received, heated and chilled)	1.9	0.4	4.8	4.4	232
Nos. 58 and 59	Heated Samples	2.2	0.9	3.0	2.1	96
	All Samples (As received, heated or chilled)	2.8	0.9	6.8	5.9	210

$$\text{Percentage Variation} = \frac{\text{Maximum} - \text{Minimum}}{\text{Average}} \times 100$$

NOTE.—Figures shown are exclusive of results reported by Analyst No. 3.

Many promising leads have been opened by the work of the past year. The sub-committee has reason to believe that development work now planned will lead to results which will permit it to propose definite specifications in the near future.

EXPERIMENTAL DATA

The samples distributed to the cooperators were raw linseed oil from Argentine seed, taken November 1, 1923, by F. J. Bisbee of the Bisbee Linseed Co. of Philadelphia. They were bottled December 1, 1923.

Sample No. 56.—Raw Linseed Oil, average quality.

Sample No. 57.—Identical with No. 56 but chilled for 3 hours at 20° F. (-7° C.) immediately before shipment.

Sample No. 58.—The same oil as No. 56 and No. 57 but not quite so well clarified.

Sample No. 59.—Identical with No. 58 but chilled for 3 hours at 20° F. (-7° C.) immediately before shipment.

The entire quantity of oil to be represented by each sample was carefully and thoroughly mixed for some time prior to, as well as during, the bottling for shipment, thus insuring uniformity in all sample bottles of a given oil. One entire set, comprising samples 56 to 59, inclusive, was forwarded to each member of the sub-committee with the request that the following tests be made on each sample:

1. "Foots" Test on thoroughly agitated sample as received, to be made by tentative A.S.T.M. method as described in Specifications D 51 – 18 T.
2. "Foots" Test on a portion, removed after thorough agitation, heated to 150° F. (65.5° C.) for 10 minutes and allowed to cool to room temperature (70 to 87° F.).
3. "Foots" Test on a portion, removed after thorough agitation, chilled at 32° F. (0.0° C.) for 5 hours and allowed to come to room temperature (70 to 80° F.).
4. "Foots" Test on a portion, chilled as in (3), heated at 150° F. (65.5° C.) for 10 minutes and allowed to cool to room temperature.
5. Iodine Number on the filtered oil by the Hanus Method as described in *Bulletin 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, page 138.
6. Iodine Number on the filtered oil by the Wijs Method.

The results were reported as given in Tables I, II, III, and IV.

The test for breaks or mucilaginous material of the oil was made by the following method:

Twenty-five grams of the well-mixed oil are weighed (accurately to 0.1 g.) into a 50-cc. Pyrex glass beaker. Three drops of c.p. hydrochloric acid (sp. gr. 1.19) are added and stirred thoroughly into the oil. The beaker is then placed on a wire gauze, supported by a tripod, and heated with the free flame of a Bunsen or Tirrill burner in such a way that the rate of temperature increase will be from 125 to 150° F. (70 to 85° C.) per minute. A thermometer, suspended so that its bulb is approximately in the center of the liquid, should be used to register the temperature during the heating. If the oil contains break, the evolution of bubbles attendant upon the removal of the air and moisture usually ceases at the moment of the formation of the break, which will rapidly cover the bottom of the beaker with a gelatinous mass honeycombed with bubbles of air. When the break formation has completely covered the bottom of the beaker, it should be gently dislodged with the thermometer or a glass rod but under no circumstances should the oil be agitated in any way prior to the break. When the temperature has reached 550° F. (288° C.) heating is discontinued and the oil allowed to cool to room temperature. The cooled oil and break are now transferred to a 250-cc. Erlenmeyer flask and the beaker thoroughly washed with five successive portions (of 25 cc. each) of c.p. carbon tetrachloride. These washings are added to the flask containing the oil and break. A small glass rod should be used to loosen any particles of break adhering to the sides or bottom of the beaker. The flask is now tightly stoppered and thoroughly shaken for two minutes in order to completely extract any oil which may have been included in the break. The diluted oil and break are then filtered on a Buchner funnel through filter paper previously dried to constant weight at 220° F. (105° C.) and weighed accurately to 0.001 g. (Whatman filter paper No. 4 will be found capable of giving satisfactory results for this purpose, although any similar paper capable of giving rapid and perfect filtration of gelatinous precipitates will also suffice.) Suction should be used in all cases to facilitate filtration. The break retained on the paper is washed with 50 cc. of carbon tetrachloride, which has previously been used to wash out the Erlenmeyer flask, and with three 25-cc. portions of pure solvent. Each portion should be allowed to run almost completely through the paper before the addition of the next. The paper and break are finally dried for 30 minutes at 220° F. (105° C.), placed in a glass weighing bottle which is tightly stoppered, allowed to attain room temperature and weighed accurately to 0.001 g. The increase in weight of the filter paper multiplied by 4 gives the percentage of break (by weight) directly.

Results obtained are given in Tables V and VI:

TABLE V.—DATA ON SUGGESTED NEW BREAK TEST FOR LINSEED OIL.

Laboratory	Sample No. 56	Sample No. 57	Sample No. 58	Sample No. 59
No. 1	0.26	0.26	0.41	0.41
No. 3	0.06	0.07	0.20	0.24
No. 4	0.13	0.11	0.24	0.25
No. 8	0.22	0.13	0.30	0.34
No. 9	0.15	0.13	0.39	0.17
Average	0.16	0.14	0.31	0.28

TABLE VI.—VARIATION IN BREAK DETERMINATIONS.

Sample	Average	Minimum	Maximum	Variation	Percentage Variation
Nos. 56 and 57 (all results)	0.15	0.06	0.26	0.20	133
Nos. 58 and 59 (all results)	0.30	0.17	0.41	0.24	80
Nos. 56 and 57 (excluding Analyst 3)	0.19	0.11	0.26	0.15	79

Ash determinations made upon oils by Bonney and Horn were carried out according to the method of U. S. Bureau of Standards Circular No. 82, as follows:

"(h) *Ash.*—Tare a porcelain crucible or dish. Add 10 to 25 cc. of oil, carefully weighing the amount added. Place on a stone slab on the floor of a hood. Ignite by playing the flame of a burner on the surface of the oil and allow to burn quietly until most of the oil is burned off; then transfer to a muffle or over a flame and continue heating at a very low temperature (not over a dull red) until all carbonaceous matter is consumed. Cool, weigh, and calculate percentage of ash."

TABLE VII.—DATA ON ASH DETERMINATIONS.

		ASH CONTENT, PER CENT
Sample No. 56		0.12
Sample No. 57		0.12 0.13
Sample No. 58		0.15 0.16
Sample No. 59		0.15
Average Quality Raw Linseed Oil	Ash in Break	0.10 0.11
	Total Ash	0.14 0.13 0.14 0.15
Refined Linseed Oil, Total Ash		0.07 0.08 0.08 0.07
Raw Oil Containing Rather More Than Average Foots, Total Ash		0.17 0.18
Very Footy Oil, Total Ash		0.53 0.54
Very Footy Oil		1.4

The ash on the break was made by igniting in the usual way. The results are given in Table VII.

Respectfully submitted on behalf of the sub-committee,

R. D. BONNEY,
Acting Chairman.

REPORT OF SUB-COMMITTEE VI ON DEFINITIONS OF TERMS USED IN PAINT SPECIFICATIONS

The Standard Definitions of Terms Used in Paint Specifications (D 16 - 15) contain the following definitions for "bulk" and "voids":

"*Bulk.*—The bulk of a pigment is the total volume thereof plus voids.

> "In referring to the bulk of a substance, it is often convenient to say: 'Its bulk is (say) 10 g. to the cubic inch.' In this case the word bulk is synonymous with 'apparent density' and involves a determination by a specific method."

"*Voids.*—The spaces between the particles of a pigment."

In view of the fact that these definitions do not coincide with the use that is made of these terms in the industry to-day, it was recommended at a sub-committee meeting of Committee E-8 on Nomenclature and Definitions that they be eliminated from the list of terms used in paint specifications.

The sub-committee recommends that this elimination be approved.

A special sub-committee of Committee E-8 recommended the following modification in the standard definition for "Fineness" to read as follows:

"*Fineness.*—The extent of sub-division of a substance as indicated under definite prescribed conditions."

The sub-committee recommends that this modification be approved.

Since the October, 1923, meeting, there has been such a variation in recommendations for definitions of "consistency" that it seems desirable to make no definite recommendation at this time.

Respectfully submitted on behalf of the sub-committee,

L. P. Nemzek,
Chairman.

REPORT OF SUB-COMMITTEE VIII ON METHODS OF ANALYSIS OF PAINT MATERIALS

No criticism having been received of the Tentative Method of Test for Specific Gravity of Pigments (D 153 – 23 T), as submitted by the committee in 1923,[1] it is recommended that this method be adopted as standard.

A sample of titanium pigment ("Titanox" brand) was submitted, together with a circular letter giving three methods in detail, to the members of the committee and several others. The methods of analysis, list of analysts reporting, results of analysis, and comments are given in the Appendix.

As a result of this cooperative study the sub-committee submits proposed Tentative Methods of Routine Analysis of Titanium Pigments as appended hereto.[2] It is recommended that these methods be accepted for publication as tentative.

The Gardner Method is submitted, as appended hereto,[3] as a proposed Tentative Method of Test for Coarse Particles in Paint Pigments, with the recommendation that it be accepted for publication as tentative. This method was originally published in *Circular No. 148*, Educational Bureau, Paint Manufacturers' Association of the U. S.

The thanks of the committee and the Society are due the Titanium Pigment Company, Inc., for the sample of "Titanox" contributed.

Respectfully submitted on behalf of the sub-committee,

F. W. SMITHER,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 651 (1923)

[2] See p. 859.—ED.

[3] See p. 857.—ED.

APPENDIX

METHODS OF ANALYSIS AND REPORTS OF COLLABORATORS ON THE ANALYSIS OF TITANIUM PIGMENTS

Three methods were forwarded to the members of the committee for the purpose of making an analysis of a sample of titanium pigment. The methods are given below:

METHOD (*a*). SUBMITTED BY MR. L. E. BARTON OF THE TITANIUM PIGMENT CO., INC.

DETERMINATION OF BARIUM SULFATE

Weigh a 0.5-g. sample into a 250-cc. Pyrex glass beaker; add 20 cc. of concentrated sulfuric acid and 7 or 8 g. of sodium sulfate. Mix well and heat on a hot plate until fumes of sulfuric anhydride are evolved and then heat directly over a flame to boiling for five minutes or until solution is complete. Traces of silica, if any, remain as an insoluble residue.

Cool, take up with 100 cc. of water, boil and filter off barium sulfate and silica, washing with 5-per-cent sulfuric acid to free the residue from titanium.

VOLUMETRIC METHOD FOR DETERMINATION OF TITANIC OXIDE

The volumetric method used for determination of titanium is essentially that described by P. W. and E. B. Shimer in the *Proceedings* of Eighth International Congress of Applied Chemistry; the method hereafter described differing principally in the form of reductor and also in a few details of operation.

REAGENTS

Standard Ferric Ammonium Sulfate Solution.—Dissolve 30 g. of ferric ammonium sulfate in 300 cc. of water acidified with 10 cc. of sulfuric acid; add potassium permanganate drop by drop, as long as the pink color disappears, to oxidize any ferrous to ferric iron; finally dilute the solution to 1 liter.

Standardize this solution in terms of iron. The iron value multiplied by 1.4329 gives the value in titanic oxide (TiO_2), and the iron value multiplied by 0.86046 gives the value of the solution in terms of metallic titanium.

Indicator.—Saturated solution of potassium thiocyanate.

REDUCTOR

As a reductor, a 500-cc. Pyrex glass dispensing burette is used. The internal dimensions of the burette are 1⅝ in. by 22 in.

The reductor is charged with about 1200 g. of amalgamated zinc, making a column about 12 in. high and having an intersticial volume of about 135 cc. The zinc is supported by platinum gauze covered with a ¼-in. mat of fibrous asbestos. On the mat is placed a 1-in. layer of 10-mesh zinc followed by a 6-in. layer of 20-mesh zinc and finally by a 5-in. layer of stick zinc. This form of reductor is convenient, and when used as hereafter described is adapted to maintaining a hot solution, which is essential for complete reduction of the titanium.

METHOD

The reductor is connected to a 1-liter flask for receiving the reduced titanium solution through a three-hole rubber stopper, which carries also an inlet tube for carbon dioxide supply, and an outlet tube for connecting with the suction pump.

The reductor is prepared for use by first passing through it a little hot dilute sulfuric acid followed by hot water, finally leaving sufficient hot water in the reductor to fill to the upper level of the zinc.

The hot filtrate from the barium sulfate determination is now introduced; about 100 cc. of water being drawn from the reductor into the original beaker to bring the solution to about the upper level of the zinc. The water thus removed will not contain any titanium if the operation has been conducted as described, but it serves as a safeguard and is also convenient to acidify this water with 10 cc. of sulfuric acid and reserve it on the hot plate to be used as an acid wash after the reduction of the sample solution.

The titanium solution is allowed to remain in the reductor for 10 minutes. While the solution is being reduced, the receiving flask is connected to the reductor and the air completely displaced by carbon dioxide conveniently drawn from a cylinder of the liquefied gas.

When the reduction is complete, the receiving flask is connected with the suction pump, and while still continuing the flow of carbon dioxide, the reduced solution is drawn out followed by the reserved acid wash and then three or four 100-cc. washes with hot water. The displacement of the sample solution and washing of the zinc is so regulated by means of the stop-cock that the reductor is always filled with a solution or water to the upper level of the zinc.

When the washing is complete, gradually release the suction to prevent air being drawn back into the receiving flask. Disconnect the flask, add 5 cc. of potassium thiocyanate solution as indicator and titrate immediately with standard ferric ammonium sulfate solution, adding the solution rapidly until a brownish color is produced which will remain for at least one minute.

The brown color developed at the end point indicates that an excess of ferric ammonium sulfate has been added and the depth of color is roughly proportional to such excess. Ordinarily, the excess ferric ammonium sulfate amounts to about 0.05 cc. which is deducted from the burette reading before calculating the titanium, thus increasing the accuracy of the result. It is desirable for each operator to establish for himself, by running a few blanks, the proper amount to deduct from the burette reading as a correction.

As the composition of Titanox is kept constantly very close to 25 per cent titanic oxide and 75 per cent barium sulfate, the percentage of Titanox can be calculated with sufficient accuracy for all practical purposes by multiplying the titanic oxide by 4.

METHOD (*b*). SUBMITTED BY MR. W. J. BROWN, NATIONAL LEAD CO.

Weigh 0.5 g. of the sample and 5 g. Na_2SO_4 (anhydrous) into a 250-cc. beaker; add 30 cc. of H_2SO_4 (concentrated) and heat on a hot plate and over a burner to complete solution. Cool, dilute to a volume of about 100 cc., bring to a boil, filter and wash with dilute hot H_2SO_4 (5-per-cent solution). The filtrate is evaporated to a volume of 200 cc. and transferred to the reductor while hot.

NOTE.—The reductor is the one specified under Method (*a*). The end of the reductor is immersed in the standard $KMnO_4$ solution which had previously been measured into the receiving flask. No CO_2 gas is used.

The solution, after remaining in the reductor for ten minutes, is run through and washed, first with dilute hot H_2SO_4 (10-per-cent solution) and then with hot water.

Disconnect, and to the flask add an excess of $FeSO_4$ solution and titrate back to a pink color with $KMnO_4$.

The $KMnO_4$ is standardized against $Na_2C_2O_4$ and calculated to terms of TiO_2.

The $FeSO_4$ is standardized against the $KMnO_4$.

It is found that when an H_2SO_4 solution is run through the reductor directly into the $KMnO_4$ solution, there is a reducing action on the permanganate; consequently a blank is run along with the sample. Five grams of Na_2SO_4 are weighed out, 30 cc. of H_2SO_4 added and carried along in the regular way. The correction amounts to about 1.0 cc. of $KMnO_4$ on a titration.

The method of procedure both on the sample and the blank is shown by the following examples:

Amount of sample used equals 0.5 g.
1 cc. of $KMnO_4$ " 0.008418 g. TiO_2
1 cc. of $FeSO_4$ " 0.95 cc. $KMnO_4$

$KMnO_4$ added to receiving flask	25.0 cc.
$FeSO_4$ added (in excess)	12.0 cc.
$KMnO_4$ added to titrate this excess	1.35 cc.

Total $KMnO_4$ used	equals	26.35 cc.
$KMnO_4 \asymp FeSO_4 (12 \times 0.95)$	"	10.80
$KMnO_4$ reduced by Ti	"	15.55
		0.008418
		0.1309
$0.1309 \times 2 \times 100$	equals	26.18 per cent
Correction for blank	"	1.70
		24.48 per cent TiO_2

Correction for blank:

$KMnO_4$ used in flask	25.0
$KMnO_4$ used for excess of $FeSO_4$	0.70
Total $KMnO_4$ used	25.70
$KMnO_4$ used by $FeSO_4$	24.7
	1.0

$FeSO_4$ used	26.0
	0.95
$KMnO_4$ reduced by $FeSO_4$	24.7

$1.0 \times 0.008418 \times 2$ equals 1.7 per cent

METHOD (*c*). SUBMITTED BY U. S. BUREAU OF STANDARDS

MOISTURE

Place 1 g. of the sample in a short, wide-mouthed weighing tube provided with a glass stopper. Heat with the stopper removed for two hours at a temperature between 100 and 105° C. Insert the stopper, cool, and weigh. Calculate loss in weight as moisture.

MATTER SOLUBLE IN WATER

Transfer 2.5 g. of the pigment to a graduated 250-cc. flask, add 100 cc. of water, boil for five minutes, cool, fill to mark with water, mix, and allow to settle. Pour the supernatant liquid through a dry filter paper and discard the first 20 cc. Then evaporate 100 cc. of the clear filtrate to dryness in a weighed dish, heat for one hour at 105 to 110° C., cool, and weigh.

TITANIUM OXIDE

Transfer 0.5 g. of the dried sample to a 250-cc. Pyrex beaker, add 20 cc. of concentrated sulfuric acid and 7 to 8 g. of ammonium sulfate. Mix well and heat on a hot plate until fumes of sulfuric acid are evolved, and then continue the heating over a strong flame until solution is complete (usually takes not over five minutes of boiling) or it is apparent that the residue is composed of silica or siliceous matter. Caution should be observed in visually examining this hot solution. Cool the solution, dilute with 100 cc. of water, stir, heat carefully to boiling while stirring, settle, filter through paper. and transfer the precipitate completely to the paper. Wash the insoluble residue with cold 5-per-cent (by volume) sulfuric acid until titanium is removed.

Dilute the filtrate to 200 cc., add about 10 cc. of ammonia (sp. gr. 0.90) to lower the acidity to approximately 5-per-cent sulfuric acid (by volume) and boil the solution to expel dissolved oxygen. Also prepare some boiled distilled water and boiled 5-per-cent sulfuric acid (by volume).

Wash out a Jones reductor[1] with hot, dilute 5-per-cent (by volume) sulfuric acid and hot water, leaving sufficient hot water in the reductor to fill to the upper level of the zinc. (These washings should require not more than one or two drops of 0.1 *N* potassium permanganate solution to obtain the pink color.) Empty the receiver, and put in it 25 cc. (measured in a graduate) of ferric sulfate solution (see Reagents). Reduce the prepared titanium solution as follows:

1. Run 50 cc. of the hot 5-per-cent sulfuric acid solution through the reductor at a speed of about 100 cc. per minute;
2. Follow this with the hot titanium solution;
3. Wash out with 50 cc. of 5-per-cent sulfuric acid;
4. Finally run through about 100 cc. of hot water.

Care should be taken that the reductor is always filled with solution or water to the upper level of the zinc.

Gradually release the suction, wash thoroughly the glass tube that was immersed in the ferric sulfate solution, remove the receiver, and titrate immediately with 0.1 *N* potassium permanganate solution (see Reagents).

$$\begin{aligned}1\text{ cc. } 0.1\,N\ KMnO_4 &= 0.0048\text{ g. Ti}\\ &= 0.00801\text{ g. } TiO_2\end{aligned}$$

Run a blank determination, using the same reagents, washing the reductor as in the above determination. Subtract this permanganate reading from the original reading and calculate the final reading to titanium dioxide (TiO_2) (which will include iron, chromium, arsenic, and any other substance which is reduced by zinc and acid).

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[1] Directions for preparing a Jones reductor may be found in Blair, "The Chemical Analysis of Iron," Seventh Edition, pp. 93–94 (Lippincott and Company).

DETERMINATION OF BARIUM SULFATE

Ignite and weigh the precipitate of $BaSO_4$ obtained in separating the titanium.[1]

IRON OXIDE

Prepare a standard ferric solution, the iron content of which has been determined, dilute and divide so as to obtain a solution 1 cc. equals 0.00001 g. Fe (see Reagents). Weigh a 1-g. portion of the sample, transfer without filtering to a 200-cc. flask, cool, fill to the mark, and determine iron colorimetrically in 50-cc. aliquot portions in the following manner. Transfer 50 cc. of the sample through a dry filter paper, discarding the first 20 cc., to a clean 100-cc. Nessler tube or other color comparator. Add a drop or two of 0.1 *N* $KMnO_4$ solution to oxidize any ferrous iron. The faint pink color should persist for at least 5 minutes. Add 10 cc. of ammonium or potassium thiocyanate solution (see Reagents), dilute to 100 cc., and mix thoroughly.

Compare the color immediately with a series of standards, prepared side by side with the sample in 100-cc. Nessler tubes. Prepare the standards from the standard ferric solution so as to have a range of from 0.00005 to 0.0004 g. Fe (5.0 to 40.0 cc.). Dilute these amounts with distilled water to about 50 cc. Add a drop of 0.1 *N* $KMnO_4$ to a faint pink color and then 10 cc. of the thiocyanate solution. Finally dilute all standards to 100 cc.

NOTE.—For a single sample it is more convenient to run the standard Fe solution from a burette into a Nessler tube containing the acid, 10 cc. of the thiocyanate solution and 60 to 70 cc. of distilled water until the depth of the color thus produced on dilution to 100 cc. and mixed, exactly matches the sample. From the burette reading calculate the amount of Fe. When using standards the color comparisons must be made immediately.

Calculate the total iron found to Fe_2O_3 and report as such. Calculate the TiO_2 equivalent by multiplying by the factor 1.003 and subtract this figure from the total titanium oxide.

REAGENTS

0.1 N Potassium Permanganate Solution.—Dissolve 3.161 g. of pure potassium permanganate in 1 liter of distilled water, let stand 8 to 14 days, siphon off the clear solution (or filter through an asbestos filter), and standardize as follows: In a 400-cc. beaker dissolve 0.25 to 0.30 g. of U. S. Bureau of Standards' sodium oxalate in 250 cc. of hot water (80 to 90° C.) and add 15 cc. of dilute sulfuric acid (1 : 1). Titrate at once with the potassium permanganate solution, *stirring the liquid vigorously and continuously.* The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise with particular care to allow each drop to be fully decolorized before the next is introduced. The solution should not be below 60° C. by the time the end point is reached. (More rapid cooling may be prevented by allowing the beaker to stand on a small asbestos-covered hot plate during the titration. The use of a small thermometer as a stirring rod is most convenient). The weight of sodium oxalate used multiplied by 0.8334 gives its iron equivalent. Multiply this iron (Fe) value by the factor 1.4344 (International Atomic Weights, 1921–1922) to obtain the equivalent value of titanium dioxide (TiO_2). The permanganate solution should be kept in a glass-stoppered bottle painted black to keep out light.

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[1] If sample is impure it may be necessary to purify this precipitate, using appropriate methods.

TABLE I.—ANALYSES OF TITANIUM PIGMENT.

Analyst	Method	$BaSO_4$, Single Precipitation, per cent	$BaSO_4$, Double Precipitation, per cent	TiO_2, Single Precipitation of $BaSO_4$, Hot Titration, per cent	TiO_2, Double Precipitation of $BaSO_4$, Hot Titration, per cent	TiO_2, Single Precipitation of $BaSO_4$, Cold Titration, per cent	Fe_2O_3, per cent	Moisture, per cent	Loss on Ignition, per cent	Water-Soluble Matter, per cent
No. 1[g]	Method (a)	74.66	.....	24.90	.....	.....	0.0083	0.12	....	0.57
		74.14	.....	25.05	.....	.....	.....	....	....	....
		74.20	.....	25.05	.....	.....	.....	....	....	....
		74.42	.....	.....	.....	.....	.....	....	....	....
	Average	74.36	.....	25.00	.....	.....	.....	....	....	....
	Method (b)	.....	.....	25.20	.....	.....	.....	....	....	....
		.....	.....	25.20	.....	.....	.....	....	....	....
		.....	.....	25.20	.....	.....	.....	....	....	....
	Average	.....	.....	25.20	.....	.....	.....	....	....	....
	Method (c)	74.04	.....	25.28	.....	25.20	0.0083	0.14	....	0.54
		73.64	.....	25.20	.....	25.20	.....	0.10	....	0.55
		73.68	.....	25.20	.....	.....	.....	....	....	0.61
	Average	73.79	.....	25.23	.....	25.20	.....	0.12	....	0.57
No. 2[f]	Method (a)	.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
	Average	.....	.....	24.80	.....	.....	.....	....	....	....
	Method (c)	.....	.....	24.80	.....	24.88	.....	....	....	....
		.....	.....	24.80	.....	24.72	.....	....	....	....
		.....	.....	25.12	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.88	.....	.....	.....	....	....	....
		.....	.....	24.96	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
		.....	.....	24.80	.....	.....	.....	....	....	....
	Average	.....	.....	24.87	.....	24.80	.....	....	....	....
No. 3[f]	Method (a)	75.20	73.84	23.91	23.73	23.55	0.004	0.09	....	....
		75.14	73.74	23.19	23.55	22.85	.....	....	....	....
	Average	75.17	73.79	23.55	23.64	23.20	.....	....	....	....
	Method (b)[e]	74.82	.....	24.67	.....	24.76	.....	....	....	....
		74.52	.....	24.65	.....	24.58	.....	....	....	....
	Average	74.67	.....	24.66	.....	24.67	.....	....	....	....
	Method (c)[e]	74.06	73.80	24.89	24.97	24.89	.....	....	....	....
		74.12	73.86	24.74	24.89	24.77	.....	....	....	....
	Average	74.09	73.83	24.81	24.93	24.83	.....	....	....	....
No. 4[g]	Method (a)	74.68	73.80	24.85	.....	.....	.....	....	....	....
		74.50	73.72	24.55	.....	.....	.....	....	....	....
		74.38	73.70	.....	.....	.....	.....	....	....	....
		74.34	.....	.....	.....	.....	.....	....	....	....
	Average	74.48	73.74	24.70	.....	.....	.....	....	....	....
	Method (b)	.....	.....	25.20	.....	.....	.....	....	....	....
		.....	.....	25.25	.....	.....	.....	....	....	....
	Average	.....	.....	25.23	.....	.....	.....	....	....	....
	Method (c)	73.70	.....	25.25	.....	.....	.....	....	....	....
		73.74	73.70	25.25	25.25	25.25	0.017	....	....	0.56
		73.70	73.68	25.20	25.25	25.25	0.016	....	0.15[a]	0.55
		73.68	.....	25.25	.....	25.20	0.014	....	....	0.57
		73.72	.....	25.25	.....	25.25	.....	....	....	0.55
		.....	.....	25.20	.....	25.25[c]	.....	....	....	....
		.....	.....	25.25	.....	25.25	.....	....	....	....
		.....	.....	25.25	.....	25.25	.....	....	....	....
	Average	73.71	73.69	25.24	25.25	25.25	0.016	....	....	0.56[b]

[a] At dull red heat for 20 minutes; includes moisture.

[b] Mainly sodium sulfate.

[c] Air bubbled through.

[e] TiO_2 results not corrected for Fe.

[f] Results on samples as received.

[g] Results on dry basis.

TABLE I.—ANALYSES OF TITANIUM PIGMENT (*Continued*).

Analyst	Method	$BaSO_4$, Single Precipitation, per cent	$BaSO_4$, Double Precipitation, per cent	TiO_2, Single Precipitation of $BaSO_4$, Hot Titration, per cent	TiO_2, Double Precipitation of $BaSO_4$, Hot Titration, per cent	TiO_2, Single Precipitation of $BaSO_4$, Cold Titration, per cent	Fe_2O_3, per cent	Moisture, per cent	Loss on Ignition, per cent	Water-Soluble Matter, per cent
No. 5[e]..	Method (*a*)...	74.70	73.82	.....	.....	.....	.....	....	....	....
		74.68	73.84	.....	.....	.....	.....	....	....	....
	Average.....	74.69	73.83[d]	.....	.....	.....	.....	....	....	....
	Method (*c*)....	73.66	.....	25.16	.....	.....	.....	....	....	....
		.....	.....	25.24	.....	.....	.....	....	....	....
		.....	.....	25.24	.....	.....	.....	....	....	....
	Average.....	.....	.....	25.21	.....	.....	.....	....	....	....
No. 6[e]...	Method (*c*)......	.....	.....	25.23	.....	.....	.....	....	....	....

[d] A third precipitation gave 73.64 and 73.66.

[e] Results on dry basis.

Ferric Sulfate Solution for Titanium.—A solution containing 2 per cent of iron as ferric sulfate is desired and may be prepared as follows: Dissolve 20 g. of pure iron or plain carbon steel in a slight excess of hydrochloric acid, oxidize with nitric acid, heat to fumes with about 80 cc. of sulfuric acid, and finally cool, and dilute to 1000 cc., set on steam bath, until dissolved, and filter if necessary. Add 0.1 *N* permanganate solution until a faint pink color shows that any ferrous iron has been oxidized.

Ferric ammonium sulfate may also be used (consult "Methods in Chemical Analysis" by Gooch, First Edition, p. 426).

Standard Ferric Sulfate Solution for Colorimetric Determination of Iron.—Determine the strength of the ferric solution reagent used in terms of iron and dilute and divide this solution until one is obtained of the strength 1 cc. equals 0.00001 g. Fe.

Potassium Thiocyanate Indicator.—Dissolve 20 g. of the pure salt in 1 liter of distilled water.

The analysts so far reporting are as follows:

1. W. J. Brown for R. L. Hallett, National Lead Co.
2. L. E. Barton, Titanium Pigment Co., Inc.
3. Frederick Kenney, Central Testing Laboratory, Department of Purchase, New York City.
4. E. F. Hickson, U. S. Bureau of Standards.
5. H. R. Snoke, U. S. Bureau of Standards.
6. J. E. Keefauver, U. S. Bureau of Standards.

The results of the analyses of Titanium Pigment are given in Table I.

COMMENTS BY W. J. BROWN

Comparison of the TiO_2 figures shows close agreement between Methods (*b*) and (*c*) while Method (*a*) is slightly lower. This may be due to uncertainty of complete removal of all air by CO_2 from the receiving flask. It is my opinion that aside from the fact that iron is titrated along with the titanium, the use of Method (*b*) or (*c*) is advantageous in that the end point is sharper and no elaborate lay-out is required. I think Methods (*b*) and (*c*) are very similar in operation, Method (*c*) giving a much smaller correction factor and having the advantage of working with cold solutions. I believe, however, that the time taken for reduction should be taken into consideration. The solution should remain in the reductor at least 10 minutes.

I think, also, that the use of $(NH_4)_2SO_4$ is to be preferred to Na_2SO_4 because of it being more easily removed from the $BaSO_4$ precipitate. Comparison of the $BaSO_4$ results shows higher figures where Na_2SO_4 is used.

While Method (*a*) gives a sum total nearer 100 per cent than does Method (*c*), I believe that the figures of Method (*c*) are nearer the true figures. It is my opinion that the pigment holds occluded Na_2SO_4, which is not completely removed by a water treatment and which would be more completely removed by the drastic $(NH_4)_2SO_4$–H_2SO_4 treatment.

The method for iron is open to the criticism that the amount of charge is extremely low. I have found that when a 50-cc. portion is aliquoted from 200 cc. of the solution and prepared for matching, the solution becomes turbid. This does not occur when 30 cc. are used, and I believe we are cutting the solution too far.

Removal of the titanium by passing H_2S through an alkaline-tartrate solution and filtering off the iron sulfide gives larger amounts of iron to match.

COMMENTS BY L. E. BARTON

With Method (*a*) there is no objection to the use of an excess of ferric sulfate in the receiving flask and titrating back with permanganate where the method is to be employed for the analysis of pure Titanox which does not contain iron. We prefer operating as described in the method since we frequently have samples containing iron. It apparently is not necessary to keep the solution in the reductor as long as ten minutes but we have adopted the 10-minute period as it gives ample time for displacement of the air in the receiving flask by carbon dioxide, which is important in preventing reoxidation of the solution before the titration is started.

We have discontinued using the 5-in. layer of stick zinc in the reductor and have replaced same with 20-mesh zinc, which we find is more satisfactory. Will you please change the method in this particular?

We have not had opportunity to try this Method (*b*) on the special sample of Titanox, but from previous experience we would make the same comments regarding the method as contained in your letter of August 11, 1923.

The use of ammonium sulfate instead of sodium sulfate in decomposing the sample of pigment in Method (*c*) is undoubtedly an improvement tending to prevent contamination of barium sulfate precipitate with titanic oxide.

I believe Method (*c*) is excellent in all cases where iron is not present in the sample under examination.

All determinations were carried out on sample as received without drying.

COMMENTS BY FREDERICK KENNEY

All of the comments set forth by the Bureau of Standards analysts are approved. In addition the following statements are made:

1. *For Barium Sulfate.*—Methods (*a*) and (*b*) give high results, due to occlusion of sodium sulfate. Both these methods require two precipitations for

correct results for barium sulfate. Method (*c*) gives excellent results in one precipitation.

2. ***For Titanium.***—Method (*a*) gives low and varied results, probably due to incomplete removal of air from the flask.

It is believed that the use of ammonium sulfate is preferable to that of sodium sulfate, as a negligible amount of titanium is retained by the barium sulfate in one precipitation.

Relative to the element of time, it was found that Method (*c*) requires the least amount of time, and Method (*a*) the greatest.

Reduction of titanium at room temperature takes place as readily as at the higher temperature.

The volumetric methods only were investigated.

An endeavor is being made to perfect a method for the titration of the reduced titanium with a standard solution of a ferric salt.

COMMENTS BY E. F. HICKSON AND OTHER BUREAU OF STANDARDS ANALYSTS

Method (*a*).—Tried out several times and the results obtained for TiO_2 were always too low. The use of CO_2 is unnecessary if ferric alum is used in the receiver. Uncertainty of the complete removal of all the air by the CO_2. Extra trouble using CO_2. Greater chance of the oxidation of the titanous sulfate than the ferrous sulfate. The subsequent titration with ferric sulfate using potassium thiocyanate indicator gives an end point that is not as sharp as that with $KMnO_4$ when ferric sulfate is used in the receiver. The long period (10 minutes) of reduction is unnecessary as titanium is as easily reduced as is iron (a speed of about 100 cc. per minute is satisfactory). In the determination of barium sulfate high results were obtained, owing to the retention or occlusion of sodium sulfate. On dissolving this precipitate in sulfuric acid and reprecipitating, results were obtained in accordance with those found by Method (*c*) with one precipitation. The method has the advantage of not including any iron with the titanium in the burette reading.

Method (*b*).—Not as convenient as Method (*c*), two standard solutions are necessary. The use of $KMnO_4$ solution in the receiver is not good practice and is unnecessary as ferric sulfate does as well. The holding of the titanium solution in the reductor for 10 minutes is unnecessary (a speed of about 100 cc. per minute is satisfactory). The method gives a high blank, and there are no apparent advantages over Method (*c*).

Method (*c*).—The method for $BaSO_4$ is superior to Method (*a*) in that with commercially pure "Titanox" correct results are obtained without a second precipitation. The reduction and titration are easier and less liable to accidental errors than in Methods (*a*) and (*b*). Has the disadvantage that a separate iron determination must be made, and if iron is present in appreciable amount in the sample, correction must be made for it. (This is also true of Method (*b*)). The reduction of titanium in a Jones reductor is conveniently carried on in solutions containing 3 to 5 per cent by volume of H_2SO_4 and may be done at any temperature between 25 and 100° C.

REPORT OF SUB-COMMITTEE IX ON VARNISH

The work of the past year has been the continuation of the investigation of the varnish tests which has been discussed in previous reports.[1]

Due to the size of the committee, sub-divisions were asked to work on various subjects and to report at a meeting which was held March 25, 1924, in New York City.

Drying Test

Messrs. Ingalls, Kinney, Sanderson and Howe make the following report:

In the report of Sub-Committee IX, 1922,[2] a record was made of the drying time of four different varnishes as recorded by twelve different operators.

Taking the time of "drying to touch," reports on Varnish A vary from 1 to $3\frac{1}{2}$ hours; Varnish B, $3\frac{1}{2}$ to $8\frac{3}{4}$ hours; Varnish C, $3\frac{1}{2}$ to $11\frac{1}{2}$ hours; Varnish D, $1\frac{3}{4}$ to $5\frac{1}{2}$ hours. These wide variations might have been due to a number of causes. First, the operators were not looking for the same end point. Second, the mechanics of the test were not well enough defined. Third, variations in temperature and humidity or other atmospheric conditions were too great.

It was first thought that a more mechanical method of telling when a varnish was "dry to touch" or "dry hard and tough" was needed. The various methods that have been suggested have not brought forth any which has been promising or substantially better than the touch method so universally used.

Two samples of varnish were sent out to the various members of the sub-division, Varnish E and Varnish F. The members were requested to test these varnishes for drying to touch according to the methods outlined in the instruction contained in our 1922 report with the exception that tests be made along the line 5 cm. (2 in.) from the top edge of the film. (Thus reducing the great variation in the thickness of the varnish which had considerable effect upon its drying.) Further, that a varnish shall be considered to be dry to touch when the film can be lightly touched with the finger without leaving an impression. This was decided as a better end point than the time when the varnish no longer adheres to the finger. In actual experience it is not always easy to decide when the varnish no longer adheres, whereas an impression left on the film is more easily observed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 375 (1922); Vol. 23, Part I, p. 269 (1923).

[2] *Loc. cit.*

On Varnish E the four operators made an aggregate of eleven different tests and the time of "drying to touch" was found varying from 3 to 4½ hours. On Varnish F, the four operators made an aggregate of nine different tests and the time of "drying to touch" varied from 4 to 5 hours. Both Varnish E and Varnish F dried "hard and tough" in less than 24 hours.

These results showed much greater uniformity than those recorded in the 1922 report and are probably in as close agreement as it is possible for different operators to obtain, working under different conditions of temperature, humidity, etc. While it is commonly believed there is not much change in the temperature or humidity conditions in a 24-hour period, a graphic record of the temperature changes in the laboratory of one member shows a condition rather surprising and a variation of 40° F. daily during the winter and a variation of 15 to 20° F. during the summer. Both the temperature and humidity should be carefully controlled in any research work in varnish testing. It is not considered feasible to write any such control of the conditions of the testing into tests which are to be used in specifications. Further work will be carried out.

FLASH POINT

Holton, Graves and Heckel recommend the adoption of the present A.S.T.M. Standard Method of Test for Flash Point of Volatile Flammable Liquids (D 56 – 21) for oleo-resinous varnishes.

VISCOSITY

Bloch and Gardner recommend that viscosity be determined by comparison with a secondary standard of known absolute viscosity.

WATER TEST

Mr. Stoppel presents his interpretation of the water test in a paper of such value that the committee recommends that it be made a part of the sub-committee report. It is appended hereto.

Sub-Committee IX recommends that the present Tentative Methods of Testing Oleo-Resinous Varnishes (D 154 – 23 T)[1] be advanced to standard with the following minor changes:

Section 3.—Add a note to read as follows:

"NOTE.—Stabilized caramel solutions or other permanent colored liquids may be used as secondary standards."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 655 (1923).

Section 8 (a).—Add a note to read as follows:

"*Note*.—The 50-per-cent standard Run Kauri reduction is given to illustrate the method. Any other percentage of standard Run Kauri reduction may be used, depending on what is required of the particular sample being tested."

The sub-committee also recommends that the following additional tests be published as tentative methods of testing oleo-resinous varnishes.

"*Flash Point*.—The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids (Serial Designation: D 56) of the American Society for Testing Materials.

"*Viscosity*.—Viscosity shall be determined by comparison at 25° C. (77° F.) with secondary standards whose viscosity expressed in poises has been accurately determined at that temperature.

"NOTE.—Gardner-Holdt tubes may be used. See *Circular No. 178*, Scientific Section, Paint Manufacturers' Association of the U. S.

"*Water Test*.—The varnish shall be poured on one of the standard tin panels and allowed to drain in a nearly vertical position and dry for 48 hours. The panel shall be placed in a beaker containing about 7 cm. (2.5 in.) of distilled water at room temperature (immersing the end of the panel which was uppermost during the drying) and left in water for 18 hours. The panel shall then be removed from the water, wiped carefully, and allowed to dry out at room temperature. The time required for whitening, if any, to disappear, shall be noted. The results of the water test shall be reported as follows:

"(1) Not visibly affected.

"(2) Whitening disappears within 20 minutes.

"(3) Whitening does not disappear in 20 minutes, but does disappear within 2 hours.

"(4) Whitening does not disappear within 2 hours, but does disappear within 24 hours.

"(5) Whitening does not disappear within 24 hours.

"Blooming, which sometimes occurs on immersion, is considered as a degree of whitening."

Respectfully submitted on behalf of the sub-committee,

E. J. COLE,
Chairman.

APPENDIX

INTERPRETATION OF THE WATER TEST

BY E. A. STOPPEL[1]

Sub-Committee IX on Varnish of Committee D-1 has undertaken to devise or standardize methods for the testing of varnish. One test on which much time has been spent is the Water Test. This consists in immersing a 48-hour air-dried film on clean tin in distilled water for 18 hours at room temperature. Under this treatment some varnishes are unaffected while others soften and whiten more or less. On removal from the water some varnishes return to normal in a few minutes; others take hours or may remain white. What do these results mean and how are they to be interpreted?

Most of the author's work on varnishes was done during the World War in testing varnishes for airplanes, where an extremely waterproof, elastic and durable varnish was desired. Varnishes tested, however, included practically everything from a polishing varnish to a heavy bodied oil with thinner. Durability varied from a few weeks to about a year exposed in the customary manner.

The purpose of varnish is to beautify and give protection to the surface over which it is applied. The qualities of the varnish film itself that need to be considered are color, hardness, elasticity, fullness, gloss, durability, resistance to abrasion, and resistance to water. Other qualities referring to the application of varnish include brushing, flowing, leveling, rubbing, polishing and drying. The ideal varnish would possess all these desirable qualities to the highest degree, that is, it would be so hard that it could not be scratched, yet elastic enough so it could be stretched without rupture, flow out to an absolutely smooth surface, would be non-whitening and last forever. Unfortunately, some qualities must be sacrificed in order to develop others. For instance, in a piano varnish, we must sacrifice some durability and water resistance to secure the necessary rubbing and polishing qualities. In automobile finishing varnishes we must sacrifice some fullness and non-whitening to secure working, flowing and durability. A varnish intended for a specific purpose, if properly made, should possess those particular qualities which are essential for that work, to the highest extent obtainable with the minimum sacrifice of the other qualities.

The testing of varnish is not a simple matter. The usual custom is to try out the varnish under actual conditions, including a service test. This is frequently impractical and requires a great deal of time. Fortunately some tests have been devised for determining some specific quality and these are being developed and standardized as far as possible.

Color can be designated by comparison with secondary standards.

Some work has been done on the rating of hardness by scratching or attempting to scratch a film with pencils of different degrees of hardness.

The relative elasticity or distensibility is now designated by the Kauri Test. Since durability depends largely upon this quality, the Kauri Test gives indirectly a valuable indication of durability.

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[1] Valentine and Co., Brooklyn, N. Y.

In these tests we try to determine some particular quality of the varnish. Now what quality or qualities can be judged by the Water Test? Some tests made on the waterproofness or permeability of varnish films may be of interest in this connection.

One test was to determine the effect of thickness of film on permeability. Bass wood panels 4 by 8 by ½ in. were carefully sandpapered and edges and corners rounded off. These were given four brush coats two days apart and then completely immersed in water. The panels were removed at intervals over a period of several weeks or months, wiped dry and weighed. The varnishes selected showed no whitening on the Water Test and flow coats measured 3 in. from the top of a glass panel ranged from 15 to 45 microns in thickness. Duplicate or triplicate panels were prepared in all cases. The increase in weight of the panels was closely inversely proportional to the thickness of the coating measured on glass. This result is quite logical.

On another test, varnishes were tried showing little or no whitening on the Water Test but cracking at various percentages of reduction on the Kauri Test. The results of this test showed the higher the percentage of gum, the less permeable the film.

Another immersion test was run to determine the permeability of films showing more or less whitening on the Water Test. Having previously determined that permeability depended upon thickness of film and on gum-oil ratio, only varnishes giving films of normal thickness and passing 50 per cent reduction on the Kauri Test were used. The results of this test showed that the amount of water absorbed by the panels was, as closely as could be judged, in proportion to whitening shown on the Water Test. It was further noted that it made no difference whether whitening was due to the presence of lime in the varnish or other causes. This was confirmed in a separate test. The tests so far show decrease in permeability:

1. As thickness of film increases;
2. As proportion of gum increases;
3. As whitening of film decreases.

These tests were all made on fresh varnish films, that is, only a few days air-dried before immersion. The films were in perfect condition so that the increase in weight of the panels was due to the water which had actually passed through the unbroken varnish film. Mr. L. V. Pulsifer carried on similar tests, carrying some of them much further. He submitted similar varnishes to alternate periods of immersion and weather exposure. On this test he noted not only that panels coated with non-whitening varnishes absorbed less water than others, but that the permeability of all varnishes decreased during exposure until the varnish checked and from that time on water resistance fell off very rapidly. A few checks only on a panel more than doubles the rate at which that panel absorbs water when again immersed. This brings out that although a high-gum varnish may be highly impermeable to water when fresh, it may soon lose this characteristic on exposure.

Frequent exposure tests have been made on many commercial varnishes by the usual out-door method. Where the varnish was intended for a marine work or for particularly waterproof purposes this exposure test was replaced or supplemented by a weather and Water Test. This consisted in exposing regular exposure panels in the regular way for a week at an angle of 45 deg. facing south, then floating the panels on water, face down for a week. The panels were then again exposed and the cycle repeated until the varnish perished. On this test, non-whitening varnishes stand up nearly as well as on straight exposure, but varnishes that whiten are far shorter lived.

From many Water Tests made on wood, plain tin and japanned tin and from the above tests certain conclusions have been drawn regarding the relation of water and varnish. First, no varnish film is absolutely impermeable so as to allow no water to pass through. It is frequently stated that varnish films have pores through which the water passes. I do not believe that this is the case. I have found that in making immersion tests with wooden panels it was necessary to give the panels at least four coats to insure sealing all of the pores of the wood. Thus sealed, duplicate or triplicate panels immersed for a week would check with each other within a few tenths of a gram. The amount of water the panels absorbed from week to week was also constant within the accuracy of the experiment. If the film were porous, no such check could be expected. My theory is that water actually dissolves in the varnish film. The amount of water that dissolves in the film may be only a few tenths or even hundredths of 1 per cent. H. A. Nelson has shown that varnish films are much more elastic in a humid atmosphere than when desiccated.[1] This is conclusive evidence that some water dissolves in the varnish film. During immersion, water passes into the film on one side and through into the wood on the other. The rate at which the panels increase in weight then depends upon the solubility of water in the varnish film and the thickness through which the water must diffuse. This being true, duplicate panels carefully prepared should check very closely in an immersion test and the rate at which water is absorbed should also be constant. This has been found to be true in the tests.

Now if we have our film on tin, glass, or some other non-absorbent surface, we soon arrive at a point where the film becomes saturated. In some cases the passage of water into the film stops but in other cases it does not. This excess water which passes into the film causes precipitation and an emulsion within the film and this is observed as whitening. The question may be asked as to why this excess water should pass into the film. The film may contain small quantities of water-soluble substances. These may be originally present in the varnish or they may be formed during the drying. Numerous investigators have found that during the oxidation of linseed oil considerable quantities of water-soluble acids are formed. Since these are formed continually some are quite certain to remain in the film. When water enters such a film the soluble compounds, dissolving in the water, produce a solution capable of exerting an osmotic pressure. The film itself acts as a dialyzing medium. Because of this osmotic pressure more water tends to pass into the film. When more water enters than is soluble in the varnish film, precipitation of the solution takes place. This results in an emulsion of water in the varnish. Because of the difference in refractive index of the two substances this is noted as whitening. Varnishes whiten less in salt or sea water than in distilled water and this is quite in accordance with the theory. Slightly whitened films return to normal as soon as the excess water dries out but badly whitened ones remain white owing, possibly, to the water being held in chemically or because the evaporation of the globules of water from within the film may have left it in a porous condition. Any whitened film can usually be restored by a dehydrating agent such as heat or alcohol but not by turpentine. A film that has once been whitened and returned to normal after drying can be more readily whitened by a second immersion and after repeated immersion and drying out will remain white.

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[1] H. A. Nelson, "Physical Properties of Varnish Films Indicated by Stress-Strain Measurements," *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 290 (1923).

To determine the relationship of water-resistance and durability we must understand why a varnish perishes. A varnish begins to perish when it has become so inelastic, or lost its distensibility to such an extent, that it cannot contract and expand in conformity with the surface over which it is applied, without rupture. In this connection we must remember that both the varnish and the surface over which it is applied expand and contract with changes of temperature. It is the difference in the rate of expansion and contraction that causes cracking.

I do not believe the coefficient of expansion of a varnish film has been determined. The coefficient of expansion of linseed oil is 0.0007 per 1° C., and it is very likely that the coefficient of expansion of a dried varnish film is also in this vicinity. The coefficient of cubical expansion of steel is about $\frac{1}{25}$ of this amount. Aluminum is about $\frac{1}{16}$. Wood is also low and we all know that prolonged heat usually causes a shrinkage rather than expansion. So it is really the varnish that expands and contracts most. However, the net result is the same.

Regardless of what the elasticity of the varnish film may have been when first applied, it eventually becomes so hard and brittle that it cracks with changes of temperature. This brittleness is brought about through the continual oxidation and hydrolysis of the varnish. I am using "hydrolysis" here in the broad sense meaning "destruction by water". These reactions not only produce brittleness but also a shrinkage in volume which alone aids cracking.

Oxidation and hydrolysis have been mentioned. Oxygen aided by light is perhaps the chief destructive agent but with moisture added we have a much more destructive combination. On our weather and water test the actual weather exposure time is only 50 per cent, and water immersion 50 per cent, yet the most water-resistant varnishes perish in the same time that they do on continuous exposure, while non-resistant varnishes crack or perish much sooner. Just what part water plays in the destruction I cannot explain, but water plays such an important part in nearly all our chemical reactions it is only natural that it should do its part here. In a varnish film supersaturated with moisture, or even below the saturation point but very permeable, we have an excellent condition for hydrolysis—hydrolysis together with the continual oxidation, brittleness, cracking and ultimate perishing.

I do not mean that the Water Test gives us an indication of durability in the same sense as the Kauri Test. Durability, as is commonly used in testing, is judged by the time required to reduce the elasticity of the varnish film to the point where it ruptures by natural changes of temperature. The Kauri Test indicates the relative elasticity of the film at the start. This elasticity is destroyed by oxidation and hydrolysis. Just to the extent that hydrolysis takes place in addition to the ordinary oxidation, just to that extent does it affect durability. Whenever a varnish in service is exposed to moisture long enough so the film can absorb any quantity of water, especially if it whitens, then water can play an important part in its destruction.

The importance of the Water Test in influencing durability depends upon the use to which the varnish will be put in service. For instance, if a varnish is to be used indoors so that, barring accidents, moisture can play no part in its destruction, then the Water Test becomes relatively unimportant. But if it is to be used for marine work, or where the atmosphere is very damp and the surface liable to be submerged or sprayed, then the Water Test becomes equally important with the Kauri Reduction Test for judging durability. This may explain why the Kauri Test does not always agree with the exposure test, or exposure tests made under different conditions may not agree with each other.

During the work on airplane varnishes all exposures were made out of doors at 45 deg. facing south. No deviation from the expected durability as indicated by the Kauri Test could be detected on varnishes that showed slight whitening on the Water Test. Nevertheless, I believe that if two varnishes were found that were exactly alike in other respects and one whitened and the other did not, the one showing no whitening would outlive the other. Given a little leeway on the Water Test, however, the manufacturer can often develop other qualities so that the resulting varnish will be more suitable for the purpose intended. I believe more efforts have been expended in producing the best finishing varnishes for automobiles, than any other varnish. Yet if the Water Test were run on the most satisfactory finishing varnishes to-day, I doubt whether any would be found that showed absolutely no whitening. This is in spite of the fact that they are often subjected to severe water tests in service. No doubt the lack of waterproofness affects the durability, but in this type, fullness and especially working and flowing are paramount. If a finishing varnish were produced that was unaffected in the Water Test and yet possessed the other requisite qualities, the durability would be greatly increased.

It would be ideal if the results of the Water Test could be expressed numerically. This cannot or has not been done so far. According to the nomenclature I have been using, varnishes were rated as follows:

1. *Unaffected.*—Varnishes showing no whitening.
2. *Very Slight Whitening.*—Some whitening visible but less than No. 3.
3. *Slight Whitening.*—Film blueish white but not completely opaque.
4. *Whitening.*—Film white and opaque.
5. *Bad Whitening.*—Worse than No. 4.

In the testing of airplane varnishes the immersion test was 48 hours and numerous varnishes tested whitened badly in that time. I doubt whether any varnishes would be classed No. 5 by an 18-hour immersion. This classification is entirely arbitrary, but I believe it is the best that can be done at present. When we note the time required for whitening to disappear the test is capable of closer refinement. In doing so the panels should be wiped with a chamois so no drops of water are left on it. I would suggest that the rating by this method be as follows:

1. Not visibly affected.
2. Whitening disappears in 20 minutes.
3. Whitening disappears in 2 hours.
4. Whitening disappears after 2 hours.
5. Permanently white.

Blooming, which sometimes occurs on immersion, is considered as a degree of whitening. The classification of varnishes by this scheme coincides very closely to the previous classification.

The author is in favor of immersing in boiling distilled water for 15 minutes. The whitening can be judged at once and the panels removed and examined for other qualities, such as hardness or tack. All varnishes are softened more or less but I have seen some varnishes actually melt and float to the surface on this test. In service such a varnish would become very soft and tacky when heated or during hot sultry weather.

In conclusion then, the water test indicates:

1. Whether the beauty of the varnish will be destroyed by contact with water;
2. The relative protection against moisture the varnish gives to the surface over which it is applied;
3. That this test considered with the Kauri Test gives a more reliable indication of the durability.

No hard and fast rule can be given regarding the maximum allowable whitening on varnishes for different purposes. For marine work where waterproofness is the prime requisite, absolute non-whitening may be insisted on. For other work, both inside and out, other qualities of the varnish must be taken into consideration, so that only the maximum waterproofness consistent with the other requirements can be secured.

REPORT OF SUB-COMMITTEE XII ON TURPENTINE

The sub-committee has endeavored during the past year to secure the approval of its specifications for turpentine and their use by the American Railway Association. This matter has been chiefly in the hands of James H. Gibboney, who is a member of the sub-committee and also of the corresponding committee of the American Railway Association. Mr. Gibboney has advised the sub-committee, under date of March 24, that he believes it can safely be assumed that the American Railway Association will go along with the American Society for Testing Materials in the handling of this matter.

The makers of destructively-distilled wood turpentine have practically unanimously urged the sub-committee to establish specifications for destructively-distilled wood turpentine, since this class of wood turpentine will not meet the existing specifications as to specific gravity and more especially as to the quantity distilling below 170° C. The makers of destructively-distilled wood turpentine ask that the requirement for specific gravity at 15.5°/15.5° C. be made 0.857 to 0.875, and that the temperature at which 90 per cent shall distill, at a pressure of 760 mm., be made 180° C. This matter was carefully considered at the meeting of the sub-committee held at the Bureau of Standards on April 25, and it was felt that the sub-committee did not have enough information upon which to act at the time. It was therefore voted that this matter be deferred and that the Advisory Committee be requested to add a representative of the producers of destructively-distilled wood turpentine to the Sub-Committee on Turpentine, in order that the sub-committee might have the full benefit of the viewpoint of these producers.

It is recommended that the Tentative Specifications for Turpentine (D 13 - 21 T)[1] be advanced to standard.

Respectfully submitted on behalf of the sub-committee,

F. P. Veitch,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 604 (1921).

REPORT OF SUB-COMMITTEE XIII ON SHELLAC

At the October, 1923, meeting of Committee D-1 held in Philadelphia, the chairman of the sub-committee stated that collaborative work would be undertaken to determine the relative merits of the present tentative Iodine Method for Rosin and the Modified McIlhiney Method for Rosin proposed by Percy H. Walker and Lawrence L. Steele, and described in U. S. Bureau of Standards *Technologic Paper No. 232*, March 12, 1923, on a pure orange shellac, a 5-per-cent rosin orange shellac, a 5-per-cent cut pure orange varnish, a 5-per-cent cut orange varnish containing rosin, a 5-per-cent cut orange varnish with copal, and a 5-per-cent cut orange varnish with rosin and copal.

The above samples were prepared by the chairman with the assistance of Mr. Ashby and Mr. White, and a set was sent to each member of the committee.

An investigation of a method for determining wax in shellac, proposed by F. S. White, was to be studied.

The alcohol insoluble matter in the two orange shellac samples was to be determined by the two methods described in the Tentative Methods of Testing Shellac (D 29 - 23 T) and the method of the United States Shellac Importers' Association, which at that time differed from the A.S.T.M. continuous extraction method in that it specified the use of 99½-per-cent methyl alcohol but since then the U.S.S.I. Assoc. has adopted the A.S.T.M. continuous extraction method.

A meeting of the committee was held in New York City on February 7, 1924, attended by Messrs. Ashby, Olsen, Trevithick, Whitmore, Stillwell, Knight, and Paisley. Reports were received from Mr. White, Mr. L. L. Steele and Mr. Richardson.

A subsequent meeting of the committee was held at the Chemists' Club in New York City, March 27, 1924. Messrs. Walker, Steele, Ashby, Olsen, White, Whitmore, Trevithick, Knight, and Paisley were present. A tabulated report of the results was presented to each member. The results of the tests are presented in Tables I and II. After discussion, it was decided to propose as a tentative standard, the method for the determination of wax proposed by F. S. White, as appended hereto.[1] The sub-committee further recommends that the present Tentative Methods of Testing

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[1] See p. 856.—Ed.

TABLE I.—RESULTS OF COLLABORATIVE TESTS ON SHELLAC.

Observer	Wijs Iodine Number	Bureau of Standards Petroleum Ether Soluble	Bureau of Standards Acid Number	Alcohol-Insoluble Matter			Determination of Wax	
				U.S.S.I.A. 99.5-per-cent Methyl Alcohol	U.S.S.I.A. Formula No. 1 Alcohol	Gooch Crucible Formula No. 1 Alcohol	U.S.S.I.A. Method	F. S. White Method
				SAMPLE NO. 1				
O. M. Olsen.....	.... 17.46	9.3 7.5 8.65	56.23 53.30 52.20	.... 3.92 3.78	.... 3.88 3.72	3.65 3.80 3.90	.... 5.09 4.91	4.98 5.02 4.96
H. P. Trevithick...	16.76	....	.....	....	....	....	....	....
H. F. Whitmore.	17.00 17.20	.... 6.2	....	.... 4.3	....	.... 3.75	.... 4.14	.... 3.82
A. G. Stillwell...	..... 17.83	....	....	....	.... 4.06	.... 4.46	4.64 4.44	.... 4.43
B. H. Knight......	17.9	....	.....	....	....	....	....	....
F. S. White........	16.8	....	.....	3.78	4.02	4.02-3.95	4.75	4.70
E. G. Richardson.	16.9 17.2	6.22 6.52	48 55	....	4.04 3.90	.... 3.91	....	....
J. W. Paisley....	..... 17.5	6.06 7.65	43.0 50.1	4.09	3.66	3.89	5.24	4.91 ....
L. L. Steele (Average of Four Tests on each Sample).	16.1	6.8	71.3	....	....	....	....	5.0-5.08
				SAMPLE NO. 2				
O. M. Olsen.....	.... 29.3	.... 17.6 17.5	..... 74 75.5	.... 2.34	.... 2.37 2.17	.... 2.45	.... 4.7	4.10 4.22 3.92
H. P. Trevithick...	27.77	....	.....	....	....	....	....	4.65
W. F. Whitmore...	28.4	9.98	81	2.53	....	2.06	4.08	3.75
A. G. Stillwell.....	29.0	11.01	122.8	....	2.56	2.84	4.68	4.09
B. H. Knight......	29.30	....	.....	....	....	....	....	....
F. S. White.......	27.8	....	.....	2.81	2.91	2.81	4.23	4.40
E. G. Richardson	27.7 27.1	8.79 9.35	102 109	....	2.46 2.54	.... 2.51	....	....
J. W. Paisley....	..... 28.45	11.01 10.36	73.3 81.8	.... 2.51	.... 2.29	.... 2.31	.... 4.60	.... 4.36
L. L. Steele (Average of Four Tests on each Sample).	27.1	11.3	115.2	....	....	....	....	4.28-4.37

Shellac (D 29 - 23 T)[1] be advanced to standard, substituting for Sections 8 to 14, inclusive, the following:

SAMPLING

"8. Both orange and bleached shellac give off volatile matter at temperatures approaching 100° C. Bleached shellac alters chemically at these temperatures, becoming less soluble in alcohol. For these reasons the usual method of determining water by heating in the air bath at 100 to 110° C. is not applicable in the analysis of shellac.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 658 (1923).

"9. *Dry Bleached Shellac.*—In sampling dry bleached shellac, about 1 lb. should be taken from different parts of the barrel and finely ground by running through a coffee mill. No attempt shall be made to sieve it. It should be rapidly mixed and transferred to a mason jar provided with a screw cap and rubber ring seal. The jar should be filled not more than two-thirds full, leaving room for a thorough mixing by shaking the contents. It should be kept in a cool place and tested as promptly as possible. If too warm, the shellac may tend to lump together, in which case the lumps must be broken up by shaking the bottle.

TABLE II.—RESULTS OF TESTS ON PURE AND ADULTERATED SHELLAC VARNISHES.

Observer	Sample	Iodine Value	Bureau of Standards Petroleum Ether Extract	Bureau of Standards Acid Number on Petroleum Ether Extract
L. L. Steele	No. 3	15.6	7.6	54.5
	No. 5	75.2	34.3	142.5
	No. 6	41.6	15.9	109.5
	Rosin Varnish	211.1	98.2	153.9
	Rosin	219.3	97.5	151.5
	Copal Varnish	142	50.2	139.6
O. M. Olsen	No. 3	17.35	5.2	71.2
	No. 4	56.90	28.16–23.68	173.3–186
	No. 5	79.72	30.48–32.60	208 –105
	No. 6	43.2 44.75	12.95–11.65	176.5–164.5
	Rosin Varnish	189.26	95.2	155
	Copal Varnish	146.7	......	......
	Rosin	197.3	......	......
J. W. Paisley	No. 3	17	7.25	61.8
	No. 4	54.55	25.61	135.5
	No. 5	76.55	31.83	144.4
	No. 6	44.45	16.07	114.2
	Rosin Varnish	220.25	106.0	157.9
	Copal Varnish	137.0	48.95	149.7
E. G. Richardson	No. 3	16.1	6.9	49
	No. 4	54.2	25.9	138.5
	No. 5	73.7	32.8	141
	No. 6	43.5	16.6	115.5
	Rosin Varnish	181.0	94.0	161
	Copal Varnish	130.0	46.0	153
H. P. Trevithick	No. 3	17.01	7.17	63.8
	No. 4	53.19	27.94	137

"10. *Bars or Hanks.*—In sampling bars or hanks it is recommended that a whole hank be taken. It should be crushed and ground as rapidly as possible.

"11. *Ground Bleached Shellac.*—Ground bleached shellac may be treated as above, bearing in mind that the large amount of moisture present makes rapid handling imperative.

METHOD

"12. *Dry-Bleached Shellac.*—Weigh 5 g. of the finely ground sample in a flat-bottomed dish about 4 in. in diameter and place the dish in a well-ventilated air bath for three to six hours at 38 to 43° C. One or two electric light bulbs provide a convenient source of heat. The temperature should not be allowed to rise above 43° C.

"NOTE.—With poorly ventilated ovens the drying may take much longer. Completeness of drying should be ascertained by continuing the treatment to constant weight.

"13. *Hanks and Ground Bleached.*—Proceed as in Section 12, but with the exception, that the dish and its contents be allowed to dry in the air, or in a sulfuric acid desiccator over night before it is placed in the air bath.

"14. *Orange Shellac.*—Proceed as in the case of Section 12.

"NOTE.—Dry-bleached shellac is also termed 'bone dry,' 'kiln dry,' 'vac dry,' 'bleached shellac.'

NOTES

"Average commercial orange shellac contains not over 2 per cent of moisture.

"Average commercial regular dry-bleached and dry-refined bleached shellac contain not more than 5 per cent of moisture.

"Average commercial regular and refined bleached shellac as ground, hanks or bars contain not more than 25 per cent of moisture."

The methods, when adopted as standard, will supersede the present Standard Methods D 29 - 17.[1]

The Modified McIlhiney Method for rosin submitted by Messrs. Walker and Steele in its present form was not found to be suitable for the quantitative estimation of rosin and hence it was not considered advisable to adopt this method as a tentative alternative standard method for rosin.

Future Work of Committee.—During the coming year, the sub-committee plans to draw up tentative standard methods for the analysis of shellac varnishes. This will include a suitable method for the determination of non-volatile matter and a study of the application of the Wijs iodine method for the determination of rosin in shellac varnish.

In addition, the sub-committee now feels that it is time to start work on the preparation of tentative specifications for the important grades of shellac and shellac varnish.

Respectfully submitted on behalf of the sub-committee,

JOHN W. PAISLEY,
Chairman.

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[1] 1921 Book of A.S.T.M. Standards.

REPORT OF SUB-COMMITTEE XIV ON PREPARATION OF IRON AND STEEL SURFACES FOR PAINTING

An inspection of the test panels at Altoona, Pa., was made on February 27, 1924, by sub-committee members McDonnell, Sabin and Carpenter—the panels being inspected in place on the exposure racks. This was the sixth regular inspection of these panels which had been continuously exposed since February, 1917—a period of seven years. The principal development was that the new steel panels with surfaces prepared by sand-blasting and pickling were still in very good condition, whereas panels Nos. 1 and 2, the former of which was painted over clean mill scale and the latter of which had some rusted surface and was cleaned by hand, had reached a decided point of deterioration. The panels of old steel were still in good condition without very decided differences in condition. The panels were rated with percentage figures indicating their relative condition on the basis of 100 per cent perfect; the ratings being as follows:

TEST ON NEW STEEL, ALTOONA

PANEL	DESCRIPTION	RATING
No. 1.	Clean surface, mill scale intact	40 per cent
No. 2.	Mill scale broken, some rust, hand cleaned	60 "
No. 10.	5 months' exposure to weather; hand cleaned	30 "
No. 10 (*a*).	Former Brooklyn panel No. 10 re-prepared by sand-blasting one half, hand cleaning other half; painted immediately two coats of same paint as other panels; exposed June 13, 1921.	
	Sand blast side	95 "
	Hand cleaned side	80 "
No. 3.	Sand blasted } Various conditions of atmosphere and temperature at time of painting	90 "
No. 4.	Sand blasted	80 "
No. 5.	Sand blasted	90 "
No. 6.	Sand blasted	90 "
No. 7.	Sand blasted	85 "
No. 16.	Incompletely sand blasted	75 "
No. 8.	Pickled, hot-water rinsed, neutralized, water washed	90 "
No. 9.	Pickled, cleaned as for Panel No. 8	80 "
No. 11.	Pickled, washed with cold water under pressure	90 "

TEST ON OLD STEEL, ALTOONA

PANEL	DESCRIPTION	RATING
No. 12.	Cleaned with wire brush	85 per cent
No. 13.	Cleaned with benzine, scraper and wire brush	80 "
No. 14.	Benzine applied and burned with torch, cleaned with scraper and wire brush	85 "
No. 15.	Sand blasted	80 "

A set of photographs of the panels was taken by Mr. McDonnell. These have been reproduced and are included in the Appendix to this report.

The two test panels left exposed at Brooklyn, N. Y., after the inspection of November 25, 1922, were inspected by sub-committee members Cheesman and Carpenter on June 19, 1924. These panels, their condition and ratings were as follows:

Brooklyn panel No. 6—new steel which was sand blasted and painted out-of-doors with temperature of 25 to 27° F.: No new breaks in coating but old breaks enlarged and rust on edges extended; balance of coating in good condition; rated 75 per cent.

Brooklyn panel No. 14—old steel which was brush-coated with benzine over and around rust spots, benzine burned off with torch and surface then cleaned with wire brush and scraper: Few, if any, additional breaks in coating; old breaks enlarged and rust on edges extended; balance of coating in good condition; rated 70 per cent.

Respectfully submitted on behalf of the sub-committee,

A. W. Carpenter,
Chairman.

APPENDIX

PHOTOGRAPHS OF ALTOONA PANELS, INSPECTIONS OF MAY 1, 1924.

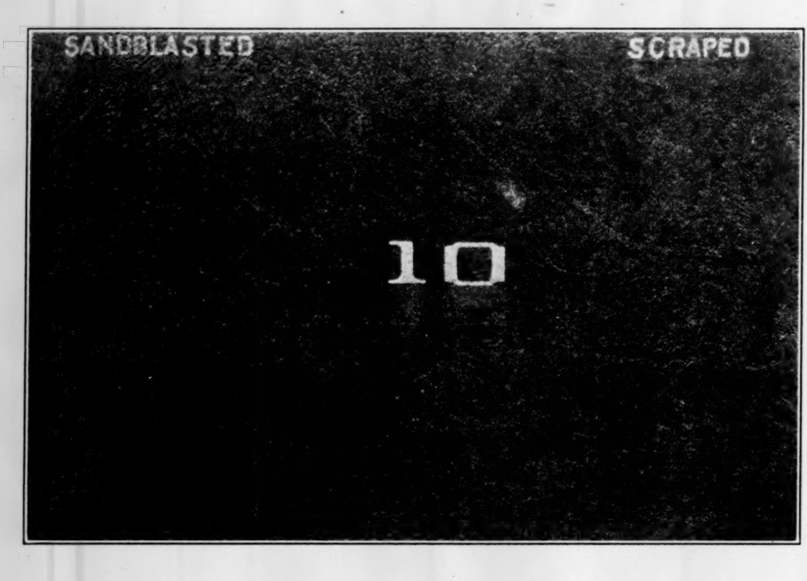

FIG. 1.—Panel No. 10–*a*, New Steel—Left Half Sand-blasted, Right Half Hand Cleaned.

Former panel No. 10 from Brooklyn, reprepared and painted two coats of same paint as other panels on June 13, 1921.

Rating.—Inspection February 27, 1924: Sand-blasted side, 95 per cent. Hand-cleaned side, 80 per cent.

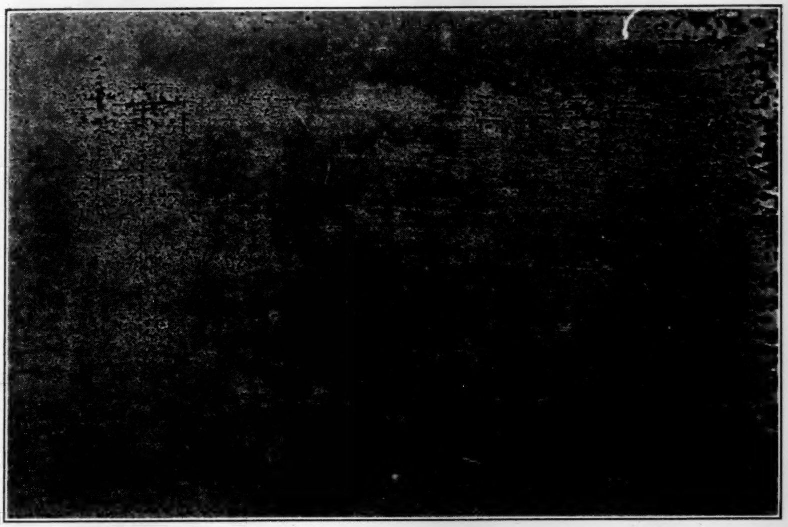

FIG. 2.—Panel No. 1, New Steel—No Surface Treatment.

As received from mill; surface clean and free from rust, mill scale intact. Paint applied in warm, dry room.

Rating.—Inspection February 27, 1924: 40 per cent.

FIG. 3.—Panel No. 3, New Steel—Sand-blasted.

Painted immediately thereafter in warm, dry room.

Rating.—Inspection February 27, 1924: 90 per cent.

FIG. 4.—Panel No. 2, New Steel—Ordinary Cleaning.

Surface rather badly abraded, about 25 per cent of mill scale gone, slightly rusted, also smeared with tallow. Washed with benzine, scraped and wire-brushed. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 60 per cent.

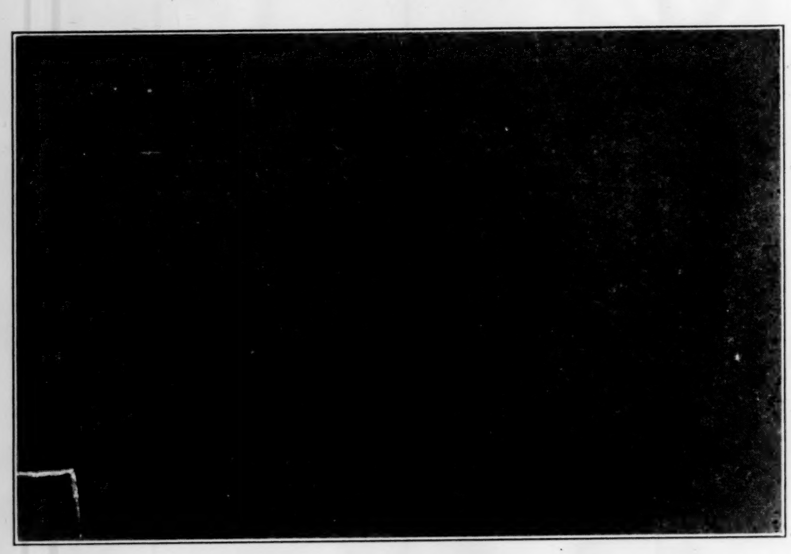

FIG 5.—Panel No. 4, New Steel—Sand-blasted.

Heated immediately thereafter in an oven to 225° F. Painted while still warm.

Rating.—Inspection February 27, 1924: 80 per cent.

FIG. 6.—Panel No. 10, New Steel—Ordinary Cleaning.

As received from mill, was exposed to weather 5½ months. Became deeply rusted, especially along diagonal lines between which some mill scale remained. Surface cleaned with scraper and wire brush. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 30 per cent.

FIG. 7.—Panel No. 5, New Steel—Sand-blasted.

Placed in cool, damp room for forty minutes and painted therein. Temperature when painted 43 to 44° F.

Rating.—Inspection February 27, 1924: 90 per cent.

FIG. 8.—Panel No. 8, New Steel—Pickled.

Rinsed under stream of hot water, neutralized with alkali solution and washed under stream of hot water. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 90 per cent.

FIG. 9.—Panel No. 6, New Steel—Sand-blasted.

Placed out-of-doors and painted there. Temperature 25 to 27° F. Both coats dried outside.

Rating.—Inspection February 27, 1924: 90 per cent.

FIG. 10.—Panel No. 9, New Steel—Pickled.

Treatment as for No. 8, and exposed out-of-doors under cover for 7 days. Some rust developed which was not removed before painting in warm, dry room.

Rating.—Inspection February 27, 1924: 80 per cent.

FIG. 11.—Panel No. 7, New Steel—Sand-blasted.

Exposed out-of-doors under cover for 7 days. Some rust developed which was not removed before painting in warm, dry room.

Rating.—Inspection February 27, 1924: 85 per cent.

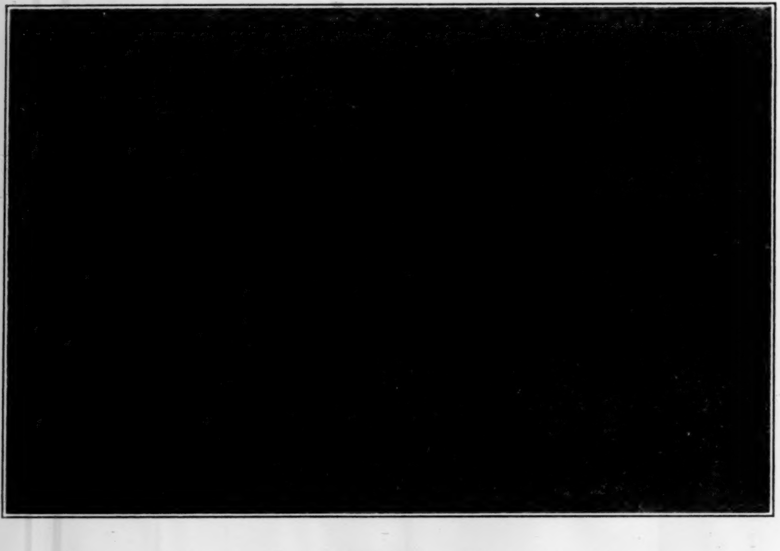

FIG. 12.—Panel No. 11, New Steel—Pickled.

Cleaned with stream of cold water under 125 lb. per sq. in. pressure. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 90 per cent.

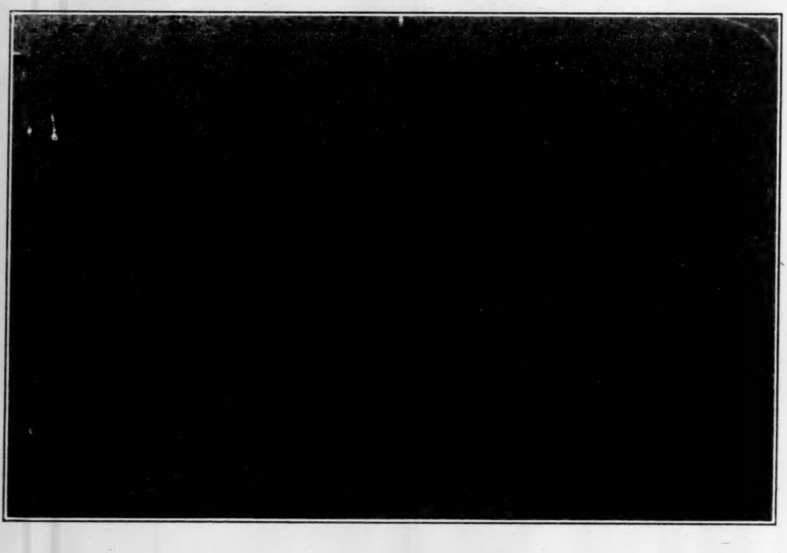

FIG. 13.—Panel No. 16, New Steel—Incompletely Sand-blasted.

Mill scale left on about 20 per cent of surface, giving "spotty" appearance before painting in warm, dry room.

Rating.—Inspection February 27, 1924: 75 per cent.

FIG. 14.—Panel No. 12, Old Steel—Wire-Brush Cleaning.

About 25 per cent of surface bare and rusted; old paint on balance. Cleaned with wire brush only, leaving old paint on about 50 per cent of surface. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 85 per cent.

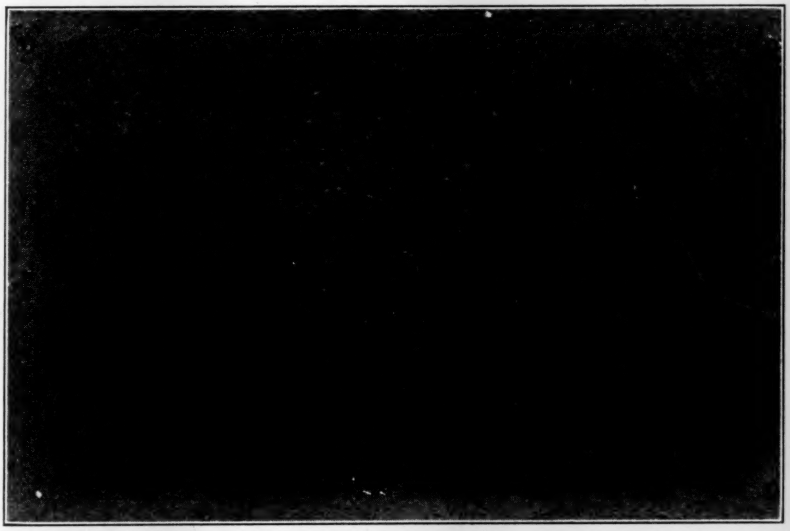

FIG. 15.—Panel No. 14, Old Steel—Burned Benzine, Brush and Scraper Cleaning.

Approximately 10 per cent of surface bare and rusted in spots, old paint on balance. Brush-coated with benzine over and around rust spots and benzine burned off with torch flame. Surface then scraped and wire-brushed. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 85 per cent.

FIG. 16.—Panel No. 13, Old Steel—Scraper, Brush and Benzine Cleaning.

About 25 per cent of surface bare and rusted in spots, old paint on balance. Washed with benzine, scraped and wire-brushed, leaving old paint on about 50 per cent of surface. Painted in warm, dry room.

Rating.—Inspection February 27, 1924: 80 per cent.

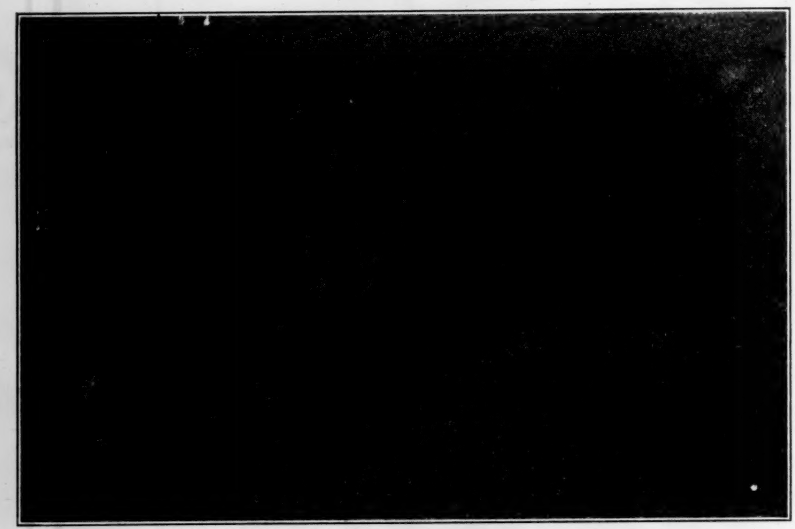

FIG. 17.—Panel No. 15, Old Steel—Sand-blasted.

Plate badly indented at several points, apparently by blows of a pick or other similar instrument. Approximately 50 per cent of surface bare and rusted. Sand-blasted in warm, dry room and painted therein.

Rating.—Inspection February 27, 1924: 80 per cent.

REPORT OF SUB-COMMITTEE XV ON SPECIFICATIONS FOR PIGMENTS DRY AND IN OIL, WHEN MARKETED IN THAT FORM

The sub-committee has held two meetings.

It is recommended that the following Tentative Specifications,[1] revised as indicated below, be submitted to the Society for adoption as standard:

For Zinc Oxide (D 79 - 21 T);
For Leaded Zinc Oxide (D 80 - 21 T);
For Basic Carbonate White Lead (D 81 - 21 T);
For Basic Sulfate White Lead (D 82 - 21 T);
For Red Lead (D 83 - 21 T);
For Ocher (D 85 - 21 T).

It is considered that the Tentative Specifications for Iron Oxide and Iron Hydroxide (D 84 - 21 T) is not yet sufficiently established to warrant adoption as standard.

REVISIONS IN TENTATIVE SPECIFICATIONS

The sub-committee recommends that the following Tentative Specifications be revised as indicated below:

For Zinc Oxide (D 79 - 21 T);
For Leaded Zinc Oxide (D 80 - 21 T);
For Basic Carbonate White Lead (D 81 - 21 T);
For Basic Sulfate White Lead (D 82 - 21 T);
For Red Lead (D 83 - 21 T);
For Iron Oxide and Iron Hydroxide (D 84 - 21 T);
For Ocher (D 85 - 21 T).

(*a*) *Coarse Particles.*—No. 325 screens being again available, it is recommended that this screen be substituted for the No. 200 now specified and that the maximum limits for coarse particles be revised to read as follows:

	Coarse Particles Retained on a Standard No. 325 Screen maximum, per cent	
	Dry Pigment	Paste
Zinc Oxide	1.0	1.5
Leaded Zinc Oxide	1.0	1.5
Basic Carbonate White Lead	1.0	1.5
Basic Sulfate White Lead	1.0	1.5
Red Lead, 85-per-cent grade	2.0	...
Red Lead, 95-per-cent grade	1.0	1.5
Iron Oxide and Iron Hydroxide	3.0	3.5
Ocher	3.0	3.5

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, pp. 615-627 (1921).

(*b*) In line with this change, revise the footnotes relating to screens to read as follows:

> "For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent."

(*c*) Omit all sections relating to methods of analysis.

Tentative Specifications for Zinc Oxide (*D 79 - 21 T*).—In order to provide for the larger absorption of refined linseed oil by French zinc oxide, revise the proportions of pigment and oil to read:

	MAXIMUM	MINIMUM
Pigment, per cent	86	80
Linseed oil, per cent	20	14

Tentative Specifications for Leaded Zinc Oxide (*D 80 - 21 T*).—Complete the requirements for proportions of pigment and oil to read as follows:

	MAXIMUM	MINIMUM
Pigment, per cent	88	83
Linseed oil, per cent	17	12

PROPOSED SPECIFICATIONS

The sub-committee recommends for consideration the following specifications, which are appended hereto as information:

For Lithopone
For Lampblack
For Bone Black
For Chrome Yellow (including lemon, medium and orange)
For Pure Chrome Green
For Reduced Chrome Green

Respectfully submitted on behalf of the sub-committee,

H. E. SMITH,
Chairman.

PROPOSED SPECIFICATIONS
FOR
LITHOPONE

Scope.

1. These specifications cover the pigment consisting of zinc sulfide and barium sulfate, commercially known as lithopone. The pigment may be purchased in the dry form or ground in oil to form a paste.

I. MANUFACTURE

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be made by suitable treatment of a mixture of precipitated zinc sulfide and precipitated barium sulfate and shall be free from admixture of any other substance.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS

Composition and Properties.

3. (*a*) In each case, the behavior on exposure to light, the mixing properties with an approved vehicle, the final consistency with this vehicle and the color shall be equal to, and the brightness and tinting strength (or hiding power) shall be not less than, those of a standard sample, mutually agreed on by buyer and seller.

(*b*) *Dry Pigment.*—The dry pigment shall meet the following requirements:

	Maximum	Minimum
Coarse particles and skins (total residue retained on a standard No. 325 screen), per cent	2.5	....
Zinc sulfide, per cent	...	26.0
Zinc oxide, per cent	1.0	....
Material soluble in water, per cent	0.8	....
Barium sulfate	The remainder	

(*c*) *Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances. The paste shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	80.0	76.0
Linseed oil, per cent	24.0	20.0
Coarse particles and skins (total residue retained on a standard No. 325 screen, based on pigment), per cent	3.0	....

Number of Tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

PROPOSED SPECIFICATIONS
FOR
LAMPBLACK

I. MANUFACTURE

Scope. 1. These specifications cover the pigment commonly known as lampblack. The pigment may be purchased in the dry form, or ground in oil or in japan to form a paste.

Process. 2. (*a*) The dry pigment shall be made by burning oils or tars in such a manner as to form a deposit of carbon or soot. The pigment shall be high grade in every respect, shall be free from oil, greasy matter and from admixture of any other substance.

(*b*) *Paste in Oil.*—The paste in oil shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

(*c*) *Paste in Japan.*—The paste in japan shall be made by thoroughly grinding the specified pigment in high-grade grinding japan.

II. PROPERTIES AND TESTS

Composition and Properties. 3. (*a*) In each case the color and tone shall be equal to, and the tinting strength not less than that of a sample mutually agreed on by buyer and seller.

(*b*) *Dry Pigment.*—The dry pigment shall meet the following requirements:

Coarse particles retained on a standard No. 325 screen, maximum, per cent	1.0
Ash, maximum, per cent	1.0
Benzol extract (which must be colorless) maximum, per cent	0.5
Tone when diluted with zinc oxide	Clear-blue-gray

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances. The paste shall meet the following requirements:

	Maximum	Minimum
Pigment, per cent	40	25
Linseed oil, per cent	75	60
Material volatile at 105° C	0.7	..
Coarse particles and skins left on a No. 325 screen (per cent of the dry pigment)	1.0	..

(*d*) *Paste in Japan.*—The paste as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brushing consistency that will dry within one hour to a hard, flat coat. It shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	40	25
Vehicle, per cent	75	60
Coarse particles and skins retained on a standard No. 325 screen (per cent of the dry pigment)	1.0	..
Non-volatile matter in the vehicle, per cent of the vehicle	..	45

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.) the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

PROPOSED SPECIFICATIONS
FOR
BONE BLACK

Scope. 1. These specifications cover the pigment commonly known as bone black, ivory black or drop black. It may be purchased in the dry form, or ground in oil or in japan to form a paste.

I. MANUFACTURE

Process. 2. (*a*) *Dry Pigment.*—The dry pigment shall be made by the calcination of bones and shall be unmixed with any other substance.

(*b*) *Paste in Oil.*—The paste in oil shall be made by thoroughly grinding the specified pigment in pure raw or refined linseed oil.

(*c*) *Paste in Japan.*—The paste in japan shall be made by thoroughly grinding the pigment in high-grade grinding japan.

II. PROPERTIES AND TESTS

Composition and Properties. 3. (*a*) In each case the color and tone shall be equal to, and the tinting strength not less than, that of a sample mutually agreed on by buyer and seller.

(*b*) *Dry Pigment.*—The dry pigment shall meet the following requirements:

Coarse particles retained on a standard No. 325 screen, maximum, per cent	2.0
Ash, maximum, per cent	85.0
Ash insoluble in acids, maximum, per cent	1.0
Benzol extract (which must be colorless), maximum, per cent	0.5
Tone when diluted with zinc oxide	Clear-blue-gray

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances. The paste shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	55	45
Linseed oil, per cent	55	45
Coarse particles and skins (total residue retained on a standard No. 325 screen, based on pigment), per cent	2.5	..

(*d*) *Paste in Japan.*—The paste as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brusing consistency that will dry within one hour to a hard, flat coat. It shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	55	45
Vehicle (japan), per cent	55	45
Coarse particles and skins (total residue retained on a standard No. 325 screen, based on pigment), per cent	2.5	..
Non-volatile matter in the vehicle, per cent of the vehicle	..	45

Number of Tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

PROPOSED SPECIFICATIONS
FOR
CHROME YELLOW

Scope.

1. These specifications cover the pigments commonly known as lemon chrome yellow, medium chrome yellow, and orange chrome yellow. The pigment may be purchased in the dry form or ground in oil, or in japan, to form a paste.

I. MANUFACTURE

Process.

2. (*a*) *Dry Pigments.*—The dry pigments, lemon chrome yellow and orange chrome yellow, shall be chemical precipitates consisting of normal or basic lead chromates or mixtures of these with or without admixtures of other insoluble compounds of lead, but without any other admixtures.

Dry medium chrome yellow shall be chemically precipitated normal lead chromate.

(*b*) *Pastes in Oil.*—The pastes in oil shall be made by thoroughly grinding the specified pigments with pure raw or refined linseed oil.

(*c*) *Pastes in Japan.*—The pastes in japan shall be made by thoroughly grinding the specified pigments in high-grade grinding japan.

II. PROPERTIES AND TESTS

Composition and Properties.

3. (*a*) In each case the color and tone shall be equal to, and the tinting strength not less than, that of a sample mutually agreed on by buyer and seller.

(*b*) The dry pigments shall meet the following requirements:

	Lemon Chrome Orange Chrome	Medium Chrome
Total matter soluble in water, maximum, per cent	0.5	0.5
Total of all substances other than insoluble compounds of lead, maximum, per cent	3.0	3.0
Organic colors or lakes	None	None
Normal lead chromate ($PbCrO_4$), minimum, per cent		97.0

(*c*) *Paste in Oil.*—The pastes as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. They shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances.

The pastes shall meet the following requirements:

	Lemon Chrome Orange Chrome		Medium Chrome	
	Maximum	Minimum	Maximum	Minimum
Pigment, per cent	85	65	82	75
Linseed oil, per cent	35	15	25	18
Water and other volatile matter, per cent	0.7	..	0.7	..
Coarse particles and skins (total residue retained on a No. 325 screen), per cent of the pigment	1.5	..	1.5	..

(*d*) *Paste in Japan.*—The pastes as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brushing consistency that will dry within one hour to a hard flat coat. They shall meet the following requirements:

	Lemon Chrome Orange Chrome		Medium Chrome	
	Maximum	Minimum	Maximum	Minimum
Pigment, per cent	85	65	82	75
Vehicle (japan) per cent	35	15	25	18
Coarse particles and skins (total residue retained on a No. 325 screen), per cent of the pigment	1.5	..	1.5	..
Non-volatile matter in the vehicle, per cent of the vehicle	..	45	..	45

Number of tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

PROPOSED SPECIFICATIONS
FOR
PURE CHROME GREEN

Scope.

1. These specifications cover what is commercially known as pure chrome green. The pigment may be purchased in the dry form or ground in oil or in japan to form a paste.

I. MANUFACTURE

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be a co-precipitated mixture of lead chromate and iron ferro and ferricyanide blue, with or without other insoluble compounds of lead.

(*b*) *Paste in Oil.*—The paste in oil shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

(*c*) *Paste in Japan.*—The paste in japan shall be made by thoroughly grinding the specified pigment with high-grade grinding japan.

II. PROPERTIES AND TESTS

Composition and Properties.

3. (*a*) In each case the color and tone shall be equal to, and the tinting strength not less than, that of a sample mutually agreed on by buyer and seller.

(*b*) *Dry Pigment.*—The dry pigment shall meet the following requirements:

Lead, present as chromate, minimum, per cent of total lead	75
Total impurities, maximum, per cent	3

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions, without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances. The paste shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	75	65
Linseed oil, per cent	35	25
Coarse particles and skins (total residue retained on a No. 325 screen), per cent of the pigment	1.5	..

(*d*) *Paste in Japan.*—The paste as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brushing consistency that will dry within one hour to a hard, flat coat. The paste shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	75	65
Vehicle (japan), per cent	35	25
Coarse particles and skins (total residue retained on a No. 325 screen), per cent of the pigment	1.5	..
Non-volatile matter in vehicle, per cent of the vehicle	..	45

Number of Tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

PROPOSED SPECIFICATIONS
FOR
REDUCED CHROME GREEN

Scope. 1. These specifications cover what is known commercially at reduced chrome green, also known as grinders green. The pigmens may be purchased in the dry form or ground in oil or in japan to form a paste.

I. MANUFACTURE

Process. 2. (*a*) *Dry Pigment.*—The pigment shall be a mixture of lead chromate and iron ferro and ferricyanide blue, with or without other insoluble compounds of lead, co-precipitated on a base of barium sulfate or insoluble siliceous material or any mixture thereof.

(*b*) *Paste in Oil.*—The paste in oil shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

(*c*) *Paste in Japan.*—The paste in japan shall be made by thoroughly grinding the specified pigment in high-grade grinding japan.

II. PROPERTIES AND TESTS

Composition and Properties. 3. (*a*) In each case the color and tone shall be equal to, and the tinting strength not less than, that of a sample mutually agreed on by buyer and seller.

(*b*) The dry pigment shall meet the following requirements:

	MAXIMUM	MINIMUM
Sum of the barium sulfate and insoluble siliceous material, per cent	80	..
Color (total of insoluble lead compounds and iron blue), per cent	..	20
Lead present as chromate, per cent of total lead	..	75
Total calcium oxide in any form soluble in acid, per cent	0.5	..
Coarse particles (total residue retained on a No. 325 screen), per cent	1.5	..

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any combination of these substances. The paste shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	88	80
Linseed oil, per cent	20	12
Coarse particles and skins (total residue retained on a No. 325 screen), per cent of the pigment	2.0	..

(*d*) *Paste in Japan.*—The paste as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brushing consistency that will dry within one hour to a hard flat coat. It shall meet the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	88	80
Vehicle (japan), per cent	20	12
Coarse particles and skins (total residue retained on a No. 325 screen), per cent	2.0	..
Non-volatile matter in vehicle, per cent of the vehicle	..	45

Number of Tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

NOTE.—For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

REPORT OF SUB-COMMITTEE XXIII ON ANTI-FOULING PAINTS

In the two previous reports, mention was made the first year of experimental studies on toxic materials and ship bottom paint vehicles in general, and the second year, the toxic ingredients of the compositions by specific methods. In the opinion of this sub-committee, the next step was to proceed to gain information by spreading upon actual ship bottoms those paints that had previously behaved most satisfactorily in our tests. This plan was followed during the past year. The results below embody the data that have so far been obtained.

During the coming year the sub-committee intends to make panel tests in detail with the various vehicles that have been proposed or appear feasible for anti-corrosive and anti-fouling paints. The tests upon ship bottoms will continue for another year.

Composition of Paints Used in Tests Upon Ship Bottoms

Anti-Corrosives:

1.	Alcohol		47.34 per cent
	Gum shellac		7.62 "
	Pine tar oil		4.57 "
	Turpentine		4.28 "
	Zinc dust		9.14 "
	Zinc oxide		27.05 "
2.	Pigment		66 per cent:
	Aluminum stearate	1 per cent	
	China clay	7 "	
	Iron oxide	75 "	
	Red lead	17 "	
	Vehicle (general formula)		34 per cent:
	Linseed oil	12.1 per cent	
	Volatile materials	72.3 "	
	Gums and resinates	15.6 "	
	Same Vehicle (as actually used)		34 per cent:
	Rubbing varnish	20.0 per cent	
	Grinding japan	33.0 "	
	Mineral spirits	6.8 "	
	Benzol	9.2 "	
	Pale gloss oil	9.8 "	
	Light naphtha	21.2 "	
3.	Red lead (98 per cent Pb_3O_4)		81 per cent
	Raw linseed oil		18 "
	Turpentine drier		1 "

4.	Benzol	18.8	per cent
	Spar varnish	2.7	"
	Plasticized benzol (Benzol containing 5 per cent of crude rubber.)	12.1	"
	Ester gum	21.9	"
	Dry zinc dust	12.1	"
	Dry zinc oxide	32.4	"

Anti-Fouling Vehicles:

(To form 60 per cent of total paint)

I.	Alcohol	58.2	per cent
	Gum shellac	19.7	"
	Pine tar oil	11.4	"
	Turpentine	10.7	"
II.	Crude mineral oil	5.85	per cent
	Pale gloss oil	81.41	"
	Solvent naphtha	6.46	"
	Grinding japan	6.28	"
III.	Rosin, Grade WW	45	per cent
	Ozokerite	2	"
	Rubber	1	"
	Petroleum spirits	52	"
IV.	Benzol	34.5	per cent
	Spar varnish	4.6	"
	Ester gum	39.4	"
	Plasticized benzol	21.5	"

Base Pigment for Anti-Fouling Paints:

(To make, along with the toxic pigment specified, a total of 40 per cent pigment in the paint)

Zinc oxide	24.3	per cent
Spanish red oxide	57.1	"
Asbestine	18.6	"

Combinations of Toxic Pigments for Anti-Fouling Paints:

(Per cent given is that for whole paint)

A.	Copper oxide, electrolytic	6	per cent
	Mercury oxide, yellow	8	"
B.	Copper oxide, electrolytic	12	per cent
	Mercury oxide, yellow	4	"
C.	Copper oxide, electrolytic	6	per cent
	Mercury arsenate	8	"
D.	Copper aceto-arsenite	6	per cent
	Copper cyanide	6	"
	Mercury arsenate	4	"
E.	Copper oxide, electrolytic	15	per cent
	Mercury oxide, yellow	1	"
F.	Copper oxide, electrolytic	5	per cent
	Copper aceto-arsenite	5	"
	Copper cyanide	5	"
	Mercury oxide, yellow	1	"

G.	Copper oxide, electrolytic	6 per cent
	Mercury oxide, yellow	4 "
H.	Mercury oxide, yellow	8 per cent
	Lead arsenate	5 "

DETAILS AS TO PAINTING SHIPS

The above Arabic and Roman numerals and the italic letters will designate the actual pairs of paints as used below. Some of these paints are duplicate combinations:

QUARTERING ON SHIPPING BOARD VESSELS:

First vessel:
Paint No. 1.—2, II, *A*.

Second vessel:
Paint No. 2.—2, II, *B*.

Third vessel:
Paint No. 3.—2, III, *C*.

Fourth vessel:
Paint No. 4.—2, III, *D*.

PATCHES ON MERCHANT VESSELS:

First vessel:
Paint No. 5.—2, II, *A*.
Paint No. 6.—2, II, *B*.
Paint No. 7.—2, II, *C*.
Paint No. 8.—2, II, *D*.
Paint No. 9.—2, II, *E*.
Paint No. 10.—2, II, *F*.
Paint No. 11.—2, II, *G*.
Paint No. 12.—2, II, *H*.

Second vessel:
Paint No. 13.—2, III, *A*.
Paint No. 14.—2, III, *B*.
Paint No. 15.—2, III, *C*.
Paint No. 16.—2, III, *D*.
Paint No. 17.—2, III, *E*.
Paint No. 18.—2, III, *F*.
Paint No. 19.—2, III, *G*.
Paint No. 20.—2, III, *H*.

Third vessel:
Paint No. 21.—4, IV, *A*.
Paint No. 22.—4, IV, *B*.
Paint No. 23.—4, IV, *C*.
Paint No. 24.—4, IV, *D*.
Paint No. 25.—4, IV, *E*.
Paint No. 26.—4, IV, *F*.
Paint No. 27.—4, IV, *G*.
Paint No. 28.—4, IV, *H*.

PATCHES ON NAVAL VESSELS:

First vessel:
Paint No. 29.—1, I, *A*.
Paint No. 30.—1, I, *B*.
Paint No. 31.—1, I, *C*.
Paint No. 32.—1, I, *D*.
Paint No. 33.—1, I, *E*.
Paint No. 34.—1, I, *F*.
Paint No. 35.—1, I, *G*.
Paint No. 36.—1, I, *H*.

Second vessel:
Paint No. 37.—2, II, *A*.
Paint No. 38.—2, II, *B*.
Paint No. 39.—2, II, *C*.
Paint No. 40.—2, II, *D*.
Paint No. 41.—2, II, *E*.
Paint No. 42.—2, II, *F*.
Paint No. 43.—2, II, *G*.
Paint No. 44.—2, II, *H*.

Third vessel:
Paint No. 45.—4, IV, *A*.
Paint No. 46.—4, IV, *B*.
Paint No. 47.—4, IV, *C*.
Paint No. 48.—4, IV, *D*.
Paint No. 49.—4, IV, *E*.
Paint No. 50.—4, IV, *F*.
Paint No. 51.—4, IV, *G*.
Paint No. 52.—4, IV, *H*.

Fourth vessel:
Paint No. 53.—1, II, *A*.
Paint No. 54.—1, II, *B*.
Paint No. 55.—1, II, *C*.
Paint No. 56.—1, II, *D*.
Paint No. 57.—1, II, *E*.
Paint No. 58.—1, II, *F*.
Paint No. 59.—1, II, *G*.
Paint No. 60.—1, II, *H*.

Fifth vessel:
Paint No. 61.—2, III, *A*.
Paint No. 62.—2, III, *B*.
Paint No. 63.—2, III, *C*.
Paint No. 64.—2, III, *D*.
Paint No. 65.—2, III, *E*.
Paint No. 66.—2, III, *F*.
Paint No. 67.—2, III, *G*.
Paint No. 68.—2, III, *H*.

Sixth vessel:
Paint No. 69.—1, III, *A*.
Paint No. 70.—1, III, *B*.
Paint No. 71.—1, III, *C*.
Paint No. 72.—1, III, *D*.
Paint No. 73.—1, III, *E*.
Paint No. 74.—1, III, *F*.
Paint No. 75.—1, III, *G*.
Paint No. 76.—1, III, *H*.

Seventh vessel:
Paint No. 77.—2, I, *A*.
Paint No. 78.—2, I, *B*.
Paint No. 79.—2, I, *C*.
Paint No. 80.—2, I, *D*.
Paint No. 81.—2, I, *D*.
Paint No. 82.—2, I, *F*.
Paint No. 83.—2, I, *G*.
Paint No. 84.—2, I, *H*.

PATCHES ON VESSELS IN DRY DOCK FOUR OR MORE DAYS:

First vessel:
Paint No. 85.—3, I, *A*.
Paint No. 86.—3, I, *B*.
Paint No. 87.—3, I, *C*.
Paint No. 88.—3, I, *D*.
Paint No. 89.—3, I, *E*.
Paint No. 90.—3, I, *F*.
Paint No. 91.—3, I, *G*.
Paint No. 92.—3, I, *H*.

Second vessel:
Paint No. 93.—3, III, *A*.
Paint No. 94.—3, III, *B*.
Paint No. 95.—3, III, *C*.
Paint No. 96.—3, III, *D*.
Paint No. 97.—3, III, *E*.
Paint No. 98.—3, III, *F*.
Paint No. 99.—3, III, *G*.
Paint No. 100.—3, III, *H*.

Third vessel:
Paint No. 101.—3, IV, *A*.
Paint No. 102.—3, IV, *B*.
Paint No. 103.—3, IV, *C*.
Paint No. 104.—3, IV, *D*.
Paint No. 105.—3, IV, *E*.
Paint No. 106.—3, IV, *F*.
Paint No. 107.—3, IV, *G*.
Paint No. 108.—3, IV, *H*.

REPORT AS TO SHIPPING BOARD VESSELS

In the inspections below, as in previous reports, no specific grades have been assigned for film condition.

Preparatory to being painted, these vessels were scraped on the bottom to the extent of the usual commercial practice. Their voyages were extensive, to the principal ports of the globe.

S. S. INDEPENDENCE:

Details as to Painting:

Anti-corrosive applied April 30, 1923. Anti-fouling applied May 1, 1923. Both dried in 15 minutes but covered poorly, with good gloss. Both were very difficult in application until thinned, as below.

Forward port quarter.—Paint No. 1.—2, II, *A*.

Aft starboard quarter.—Paint No. 2.—2, II, *B*.

One quart of petroleum spirits added to each five gallons of the above.

The other two quarters of the ship's bottom were painted with the regulation compositions, used also on the other shipping board vessels below. These compositions were as follows:

ANTI-CORROSIVE		ANTI-FOULING	
Alcohol	47.34 per cent	Alcohol	38.78 per cent
Gum shellac	7.62 "	Gum shellac	13.12 "
Pine tar oil	4.57 "	Pine tar oil	7.60 "
Turpentine	4.28 "	Turpentine	7.13 "
Zinc dust	9.14 "	Zinc oxide	13.12 "
Zinc oxide	27.05 "	Indian red	13.12 "
		Mercury oxide, yellow	7.13 "

The above regulation paints dried flat in comparison with the test compositions but covered more surface.

The painting required 60 gal. of the test anti-corrosive and 55 gal. of the regulation anti-corrosive; 35 gal. of II, *A* and 43 gal. of II, *B*, in contrast with 60 gal. of the regulation anti-fouling.

Inspection, December 10, 1923.
Present: A. C. Holzapfel, A. M. Muckenfuss.
Length of exposure of ship bottom in water: 7 months, 9 days.

The whole of the bottom had a covering of small acorn shell and coral. The preservation of 2, II, *A* and 2, II, *B* was excellent, a little better perhaps on the regulation paint. 2, II, *A* showed up slightly better than 2, II, *B* in protection from fouling.

COMPOSITIONS	GRADES	
	CORROSION	FOULING
2, II, A	9.5	6.5
2, II, B	9.5	6
Regulation	10	6.5

There is not enough difference in the behavior of these three paints to draw a definite conclusion, as to comparison.

S. S. SINSINAWA:

Details as to Painting:

Anti-corrosive and anti-fouling paints applied June 19, 1923.

Aft port quarter.—Paint No. 3—2, III, *C*.

Forward starboard quarter.—Paint No. 4—2, III, *D*.

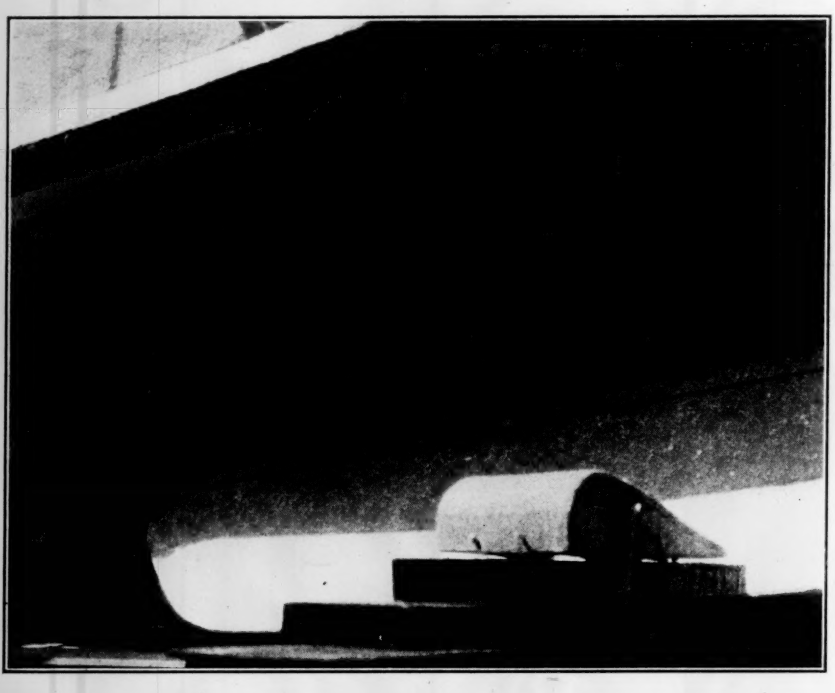

FIG. 1.—Condition of Bottom of U. S. S. Arkansas, the last week of April, 1923, after cleaning and before painting.

The anti-corrosive dried in 15 minutes, covered fair and was flat.

Anti-fouling III, *C* covered well; III, *D* covered poorly; both dried in about two hours with a good gloss.

The rest of the ship's bottom was covered with the same regulation composition as given for the "Independence."

This anti-fouling paint dried flat but covered better than III, *D*. 20 gal. to a quarter used for all paints.

This ship has not yet been inspected.

S. S. ARCHER:

Details as to Painting:

Anti-corrosive and anti-fouling paints applied June 22, 23, 1923.

Forward starboard quarter.—Paint No. 1—2, II, *A*.

Aft port quarter.—Paint No. 2—2, II, *B*.

The anti-corrosive dried in about one-half hour. The two anti-fouling paints covered well and dried in about 2½ hours. These were difficult in application.

The other two quarters of the ship's bottom were painted with the regulation compositions as given above for the "Independence."

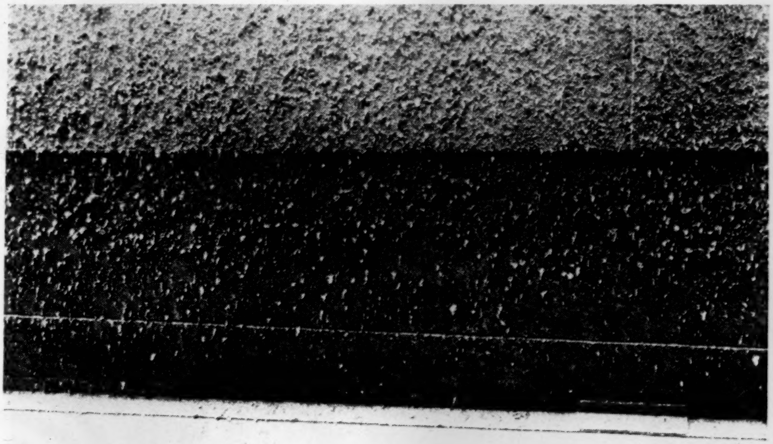

FIG. 2.—U. S. S. Arkansas, Inspection, December 27, 1923. View of starboard side, center of bilge keel. Region of paints Nos. 89 to 92.

There was used on this ship: 70 gal. of the test anti-corrosive, 45 gal. of anti-fouling II, *A*; 20 gal. of anti-fouling II, *B*; 72 gal. of the regulation anti-corrosive; and 90 gal. of the regulation anti-fouling paint. Aft port quarter was covered half with the regulation paint.

This ship has not yet been inspected.

S. S. WEST SAGINAW:

Details as to Painting:

Anti-corrosive and anti-fouling paints applied April 9, 1923.

Forward port quarter.—Paint No. 3—2, III, *C*.

Aft starboard quarter.—Paint No. 4—2, III, *D*.

The rest of the ship's bottom was painted with the regulation compositions as given for the "Independence."

The latter dried very flat. Anti-fouling paints III, *C* and III, *D* did not cover well but were more glossy than the regulation paint. There were used: 60 gal. of the test anti-corrosive, and 60 gal. of the regulation anti-corrosive; 28 gal. of anti-fouling paint, III, *C;* 29 gal. of III, *D;* and 47.5 gal. of the regulation anti-fouling.

This ship has not yet been inspected.

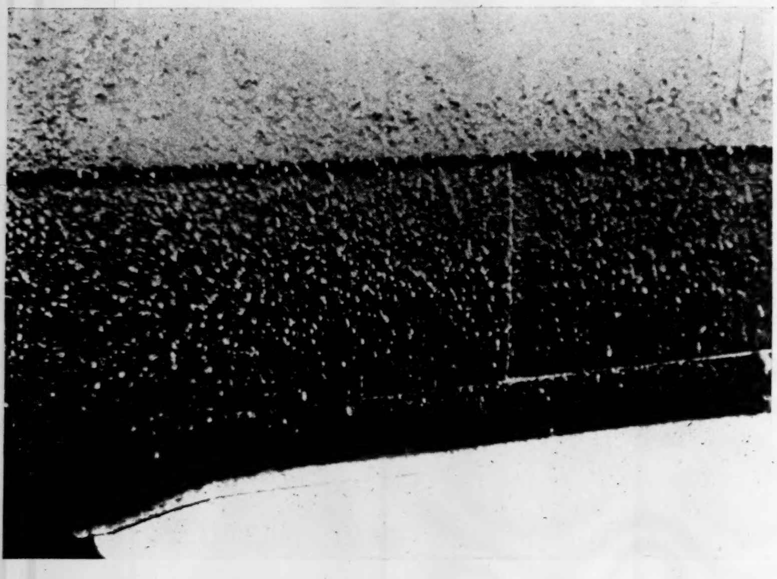

FIG. 3.—U. S. S. Arkansas, Inspection, December 27, 1923. View of starboard side, aft end of bilge keel. Region of paints Nos. 93 to 96.

REPORTS AS TO MERCHANT VESSELS

The approximate grades assigned to the paints on these vessels must be considered in connection with the fact that the old paint was not scraped off. The voyages were mainly to Cuba and Mexico and return.

S. S. MUNSOMO:

Anti-corrosive and anti-fouling patches applied, the first February 21, 1923, and the second February 24, 1923. Each patch 3 ft. wide from the 20-ft. mark down to keel, beginning 15 ft. from the stern frame on port side. The patches were applied over the old commercial paint used by the Munson Line, which was in fair condition. The rest of the ship's bottom was coated with the same commercial paint.

The following were the patches applied:

Paint No. 5.—2, II, *A*.	Paint No. 6.—2, II, *B*.
Paint No. 7.—2, II, *C*.	Paint No. 8.—2, II, *D*.

The anti-corrosive dried flat. The anti-fouling paints spread very heavy.

Inspection, November 10, 1923:
Present: Agent of International Compositions Co., Baltimore, Md.
Time at sea of ship, 8 months, 16 days.

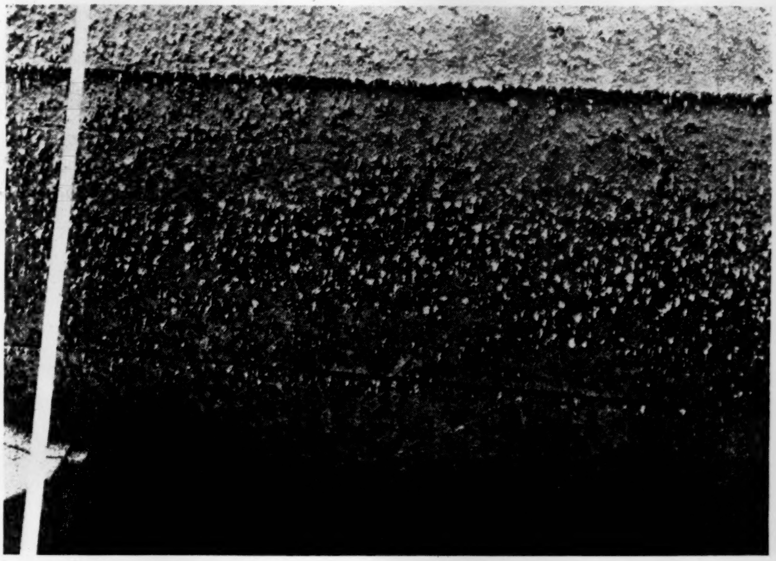

FIG. 4.—U. S. S. Arkansas, Inspection, December 27, 1923. View of port side, forward end of bilge keel. Region of paints Nos. 97 to 100.

The patches appeared as good as other parts of the ship's bottom. The entire bottom was in good shape. There was no rust or growth and the paint appeared well preserved.

Conclusions: The above results speak well for the varnish type anti-corrosive and the gloss oil type anti-fouling vehicle in the four paint patches used on this ship. It also indicates that the stronger toxic combinations (*A*, *B*, *C*, *D*) are reliable under service conditions.

S. S. MUNAIRES:

Patches applied in the same way as on the above ship, March 29, 1923. Same commercial paint used on rest of vessel. Patches applied over same commercial paint, in good condition.

The following paints were used:

Paint No. 9.–2, II, *E*.	Paint No. 10.—2, II, *F*.
Paint No. 11.—2, II, *G*.	Paint No. 12.—2, II, *H*.

Inspection, July 21, 1923.
Present: A. C. Holzapfel.
Time at sea of the ship, 3 months, 22 days.

Compositions	Grades	
	Corrosion	Fouling
Paint No. 9	10	7
Paint No. 10	10	9
Paint No. 11	10	8
Paint No. 12	10	8
Commercial paint	10	9

Details of Inspection: Corrosion none. Fouling: Paint No. 9, very thin coating of slime. Paint No. 10 and commercial paint, about one short tuft of grass to each square foot. Paint No. 11, very thin coating of slime. Paint No. 12, about one square foot of grass to each square foot. Condition of paint: No. 9, cracked. No. 10 and commercial paint, good. No. 11, few small cracks. No. 12, very slight cracks.

Conclusions: On this ship the same anti-corrosive and the same anti-fouling vehicle were used as on the previous ship. The toxic composition of paint No. 10, the best of the four in the table just given, was: copper oxide, 5 per cent; copper aceto-acetate, 5 per cent; copper cyanide, 5 per cent; and mercury oxide, 1 per cent.

S. S. MUNARDIAN:

Four patches applied in the same way as on the above ship, April 10, 1923. The same commercial paint was used on the rest of the vessel. The patches were applied over the same commercial paint, in good condition. The following paints were used:

Paint No. 13.—2, III, *A*.	Paint No. 14.—2, III, *B*.
Paint No. 15.—2, III, *C*.	Paint No. 16.—2, III, *D*.

This vessel has not yet been inspected.

S. S. MUNPLACE:

Patched exactly similarly to the other three ships above, June 7, 1923. Two coats of anti-corrosive and of anti-fouling given.

The following compositions were selected:

Paint No. 17.—2, III, *E*.	Paint No. 18.—2, III, *F*.
Paint No. 19.—2, III, *G*.	Paint No. 20.—2, III, *H*.

This vessel has not yet been inspected.

REPORTS AS TO NAVAL VESSELS

These ships were painted in wide patches from water line to keel, beginning near the stern, with an equal number of patches on both sides of the ship. The rest of the ship was protected with the regulation paints given under the "Independence," The bottoms were scraped clean before painting. The voyage was to Panama and return mainly, except as otherwise stated.

U. S. S. MARYLAND:

Painted early in April and undocked April 13, 1923. The following detailed report of inspection and tabulation will show what paints were used.

Inspection, Hunters Point, Calif., October 18, 1923.
Time of ship at sea, 5 months, 13 days.
Present: Frank H. Clark, Commanding Officer.

PAINT NO.	CONDITION OF PAINT	CONDITION OF BOTTOM
29	Good	Moderately foul
30	(Too small an area to be sure)	
31	Wearing off in spots	Moderately foul
32	Sloughing in patches	Moderately foul
33	Good	Slightly foul
34	A little sloughing	Moderately foul
35	Paint almost gone	Foul
36	Excellent	Almost clean
37	Soft and scarred	Almost clean
38	Excellent	Clean
39	Good	Slightly foul
40	Very good	Moderately foul
41	Excellent	Clean
42	Good	Moderately foul
43	Excellent	Moderately foul
44	Good	Moderately foul
45	Sloughed off in large patches	Some corrosion and barnacles
46	" " " " "	" " " "
47	Some sloughing	Moderately foul
48	Sloughed in large patches	Moderately foul
49	" " " "	" "
50	Anti-fouling worn almost off. Some sloughing in anti-corrosive	Few barnacles and generally clean
51	Anti-fouling worn almost off. Some sloughing in anti-corrosive	" " " " "
52	Sloughing in patches	Moderately clean
53	Anti-fouling worn almost through. Anti-corrosive sloughed off in patches	Generally clean and showing little corrosion
54	Anti-fouling worn off in patches	Slightly foul
55	Badly sloughed	Moderately foul
56	Badly sloughed	Barnacles and some grass
57	Patches sloughed off	Moderately foul
58	Mostly off	Barnacles and general fouling
59	Anti-fouling worn thin	Moderately clean
60	" " " "	" "

Comments: The expression "Moderately foul" refers to general condition of the ship's underbody. Paints No. 36, 37, 38, 41, 52, and 53 showed generally less fouling than the general average of the underwater body. There were little if any signs of active corrosion in the area covered by the test paints.

No.	Anti-Corrosive Comp.	Anti-Fouling Vehicle Comp.	Composition						Grades	
			Copper Oxide, per cent	Mercury Oxide, per cent	Mercury Arsenate, per cent	Copper Aceto-Arsenate, per cent	Copper Cyanide, per cent	Lead Arsenate, per cent	Corrosion	Fouling
29	Shellac....	Shellac....	6	8	..	..	..	..	10	7
30	"	"	12	4	..	..	..	..	..	..
31	"	"	6	..	8	..	..	..	9	6
32	"	"	6	..	4	6	..	..	9	6
33	"	"	15	1	..	..	..	..	10	8
34	"	"	5	1	..	5	5	..	9	6
35	"	"	6	4	..	..	..	..	6	2
36	"	"	..	8	..	..	..	5	10	9.5
37	Varnish....	Gloss Oil...	6	8	..	..	..	..	10	9
38	"	" ...	12	4	..	..	..	..	10	10
39	"	" ...	6	..	8	..	..	..	10	8
40	"	" ...	6	..	4	6	..	..	10	7
41	"	" ...	15	1	..	..	..	..	10	10
42	"	" ...	5	1	..	5	5	..	10	7
43	"	" ...	6	4	..	..	..	..	10	7
44	"	" ...	..	8	..	..	..	5	10	7
45	Ester Gum.	Ester Gum.	6	8	..	..	..	..	7	5
46	" .	" .	12	4	..	..	..	..	7	5
47	" .	" .	6	..	8	..	..	..	9	6
48	" .	" .	6	..	4	6	..	..	8	6
49	" .	" .	15	1	..	..	..	..	8	6
50	" .	" .	5	1	..	5	5	..	8	8
51	" .	" .	6	4	..	..	..	..	8	8
52	" .	" .	..	8	..	..	..	5	9	9
53	Shellac....	Gloss Oil...	6	8	..	..	..	..	7	9
54	"	" ...	12	4	..	..	..	..	9	9
55	"	" ...	6	..	8	..	..	..	8	7
56	"	" ...	6	..	4	6	..	..	8	5
57	"	" ...	15	1	..	..	..	..	9	7
58	"	" ...	5	1	..	5	5	..	7	4
59	"	" ...	6	4	..	..	..	..	9	8
60	"	" ...	..	8	..	..	..	5	9	8

TABULATION BY TOXIC COMBINATIONS, ANTI-FOULING GRADES

Paints	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Nos. 29 to 36..........................	7	..	7	7	8	7	2	9.5
Nos. 37 to 44..........................	9	10	8	7	10	7	7	7
Nos. 45 to 52..........................	6	6	7	7	7	8	8	9
Nos. 53 to 60..........................	9	8	7	5	7	4	9	9
Average..........................	7.75	8	7.25	6.5	8	6.5	6.5	8.63

Conclusions: The three anti-corrosives gave good results, the ester gum being slightly less efficient than the others. The same is true of the anti-fouling vehicles, here the gloss oil type being the most efficient. Of the toxic combinations, there was one great contrast according to vehicles present, *i. e.*, the copper, 6 per cent, mercury, 4 per cent combination rated grade 2 with the shellac and grades 7, 8, 9 with the other vehicles.

Combination *H* (copper, 4 per cent, lead arsenate, 5 per cent) tested out the best on the average, closely followed by *B* and *E*, the last being the copper, 15 per cent, mercury, 1 per cent mixture.

U. S. S. ARKANSAS:

Painted the last week of April and undocked May 5, 1923. The following detailed reports of inspection and tabulation will show what paints were employed:

Inspection, Brooklyn Navy Yard, December 27, 1923.
Time of ship at sea, 8 months, 14 days.
Present: R. L. Hallett, T. R. Collins (representing G. D. White) and Howard Nestlen (representing the Engineer Officer of the Brooklyn Navy Yard).

The regulation paint on the ship showed itself in about the same condition as the test paints tabulated below, which was the average condition for the length of service involved. This regulation paint was the same as that given for the "Independence" in an earlier portion of this report.

No.	Anti-Corrosive Comp.	Anti-Fouling Vehicle Comp.	Composition						Grades	
			Copper Oxide, per cent	Mercury Oxide, per cent	Mercury Arsenate, per cent	Copper Aceto-Arsenate, per cent	Copper Cyanide, per cent	Lead Arsenate, per cent	Corrosion	Fouling
85	Red Lead	Shellac	6	8	..	..	..	..	10	6
86	"	"	12	4	..	..	..	..	10	6
87	"	"	6	..	8	..	..	..	10	6
88	"	"	6	..	4	6	..	..	10	6
89	"	"	15	1	..	..	..	..	10	6
90	"	"	5	1	..	5	5	..	10	6
91	"	"	6	4	..	..	..	..	10	6
92	"	"	..	8	..	..	..	5	10	6
93	"	Rosin	6	8	..	..	..	..	10	6
94	"	"	12	4	..	..	..	..	10	6
95	"	"	6	..	8	..	..	..	10	6
96	"	"	6	..	4	6	..	..	10	6
97	"	"	15	1	..	..	..	..	10	7
98	"	"	5	1	..	5	5	..	10	7
99	"	"	6	4	..	..	..	..	10	7
100	"	"	..	8	..	..	..	5	10	7
101	"	Ester Gum	6	8	..	..	..	..	10	8
102	"	"	12	4	..	..	..	..	10	7
103	"	"	6	..	8	..	..	..	10	7
104	"	"	6	..	4	6	..	..	10	7
105	"	"	15	1	..	..	..	..	10	7
106	"	"	5	1	..	5	5	..	10	7
107	"	"	6	4	..	..	..	..	10	7
108	"	"	..	8	..	..	..	5	10	7

Conclusions: There is very little difference in the ratings of the different composition. Anti-corrosive: Red lead paint again shows itself a good first coat, where time is allowable for four days' drying. Anti-fouling: Shellac does not here appear to be a better binder than rosin or ester gum, properly compounded. The toxic combination of 15 per cent copper oxide with only 1 per cent mercury oxide appears to be as satisfactory on this ship as 6 and 8 per cent, respectively.

U. S. S. WYOMING:

On April 9, 1924, the battleship Wyoming was docked at the Brooklyn Navy Yard. The special anti-corrosive and anti-fouling paints applied to the hull of this ship were inspected by the following members of the A.S.T.M. Committee:

Mr. A. C. Holzapfel,
Mr. R. L. Hallett represented by Mr. Weber,
Mr. G. D. White represented by Mr. L. G. Stem.

The Wyoming has been cruising in northern waters and, therefore, there was only a slight barnacle growth in comparison to what might be expected on a ship that has been cruising in southern waters.

Paints Nos. 61 to 71, inclusive, and No. 73, were applied to the starboard side; the other paints, to the port side.

The following ratings of the different paints were agreed upon by the various inspectors, ten as usual indicating perfection:

No.	Anti-Corrosive Comp.	Anti-Fouling Vehicle Comp.	Composition						Grades	
			Copper Oxide, per cent	Mercury Oxide, per cent	Mercury Arsenate, per cent	Copper Aceto-Arsenate, per cent	Copper Cyanide, per cent	Lead Arsenate, per cent	Corrosion	Fouling
61	Varnish....	Rosin......	6	8	..	..	..	..	7	9
62	"	"	12	4	..	..	..	..	7	8
63	"	"	6	..	8	..	..	..	7	8
64	"	"	6	..	4	6	..	..	7	8
65	"	"	15	1	..	..	..	..	6	8
66	"	"	5	1	..	5	5	..	6	8
67	"	"	6	4	..	..	..	..	6	7
68	"	"	..	8	..	..	..	5	6	7
69	Shellac....	"	6	8	..	..	..	..	9	9
70	"	"	12	4	..	..	..	..	9	9
71	"	"	6	..	8	..	..	..	9	9
72	"	"	6	..	4	6	..	..	8	9
73	"	"	15	1	..	..	..	..	10	10
74	"	"	5	1	..	5	5	..	8	9
75	"	"	6	4	..	..	..	..	8	9
76	"	"	..	8	..	..	..	5	8	9
77	Varnish....	Shellac....	6	8	..	..	..	..	9	9
78	"	"	12	4	..	..	..	..	9	9
79	"	"	6	..	8	..	..	..	9	7
80	"	"	6	..	4	6	..	..	9	7
81	"	"	15	1	..	..	..	..	9	7
82	"	"	5	1	..	5	5	..	9	7
83	"	"	6	4	..	..	..	..	9	8
84	"	"	..	8	..	..	..	5	9	7

No bad barnacle growth or severe corrosion took place on any of the paints and therefore a paint with a low rating can only be considered relatively poor in comparison to the other paints on the same ship.

Conclusions: As to vehicles, shellac showed up the best of the three vehicle combinations used. As to toxic pigments, in the prevention of fouling, the best combination on the average was "A" (copper oxide, 6 per cent; mercury oxide, 8 per cent), but "B" (the 12 to 4) and "E" (the 15 to 1) were nearly as satisfactory. The best paint in the series on this ship was No. 73, containing toxic combination "E", or 15 per cent copper oxide to 1 per cent mercury oxide.

DEFINITION OF GRADES

Grade 10.—Best grade, least fouling or corrosion.

Grade 0.—Poorest grade, greatest fouling or corrosion.

PHOTOGRAPHS

Four photographs of the U. S. S. Arkansas are given in this report.

Respectfully submitted on behalf of the sub-committee,

A. M. MUCKENFUSS,
Chairman.

REPORT OF COMMITTEE D-2
ON
PETROLEUM PRODUCTS AND LUBRICANTS

Committee D-2 has held three regular meetings during the past year, namely, in June at Atlantic City, in November at Washington, D. C., and in March at New York City. In addition, an informal meeting was held in St. Louis at the time of the annual meeting of the American Petroleum Institute, which was very well attended and provided an additional opportunity for a discussion of the work of the committee.

During the year one additional sub-committee has been appointed, Sub-Committee XXIII on Carbon Residue.

The committee now has a voting membership of 36 producers and 39 non-producers. The committee regrets to report the death of two of its active members, Mr. W. C. Marckworth and Mr. J. C. Fitzsimmons.

The committee is pleased to report the adoption of the tentative standards presented last June, by the Federal Specifications Board of the United States Government, and the increased use of the various standards and tentative standards which it has prepared, by producers and consumers of petroleum products.

RECOMMENDATIONS IN REFERENCE TO PRESENT STANDARDS

The committee recommends that the present Standard Method of Test for Carbon Residue (Conradson Method) be withdrawn from the Standard Methods of Testing Lubricants (D 47 – 21)[1] and be published as tentative.

The committee recommends that the present Standard Method of Test for Free Acid in Lubricants be withdrawn from the Standard Methods of Testing Lubricants (D 47 – 21) and that the method be published as tentative, omitting all reference to alkali blue and turmeric.

RECOMMENDATIONS IN REFERENCE TO TENTATIVE STANDARDS

The committee recommends certain slight changes in the present Tentative Method of Test for Melting Point of Petrolatum (D 127 – 22 T) to be found in the report of Sub-Committee I on Petrolatum appended hereto, and upon the approval of these revisions, that the method be continued as tentative.

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[1] 1921 Book of A.S.T.M. Standards.

The committee recommends certain revisions in the Tentative Method of Analysis of Grease (D 128 - 22 T) to be found in the report of Sub-Committee IV on Grease appended hereto, and upon the approval of these revisions, that the method be continued as tentative.

The committee recommends certain revisions in the Tentative Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 - 23 T) and upon approval of these revisions, recommends that the method be continued as tentative. These revisions will be found in the report of Sub-Committee V on Viscosity appended hereto.

The committee recommends the revision of the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products (D 86 - 23 T), these revisions consisting of certain changes in the specifications for the distillation thermometers as proposed by Committee D-15 on Thermometers. This revision will be found in the report of Sub-Committee VIII on Distillation appended hereto. Upon approval of these revisions, the committee recommends that the method be continued as tentative.

NEW TENTATIVE STANDARDS

The committee is presenting for approval for publication as a tentative standard the proposed Tentative Method of Test for Burning Quality of Kerosene Oils, which will be found in the report of Sub-Committee XIX on Illuminating Oils appended hereto.

ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD

The committee recommends for submission to letter ballot of the Society, for adoption as Standard, the following tentative methods, with the revisions indicated:

(*a*) Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 - 23 T)[1] after changing the first sentence of Section 2 to read as follows:

> "The cup shall be supported by a metal plate $\frac{1}{4}$ in. (0.635 cm.) in thickness and 6 in. (15.24 cm.) in width."

This change in no way affects the substance of the method.

(*b*) Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 23 T)[2] with the addition of the following sentence at the end of the second paragraph of Section 9:

> "A loose cotton plug shall be inserted in the top of the condenser tube to prevent condensation of atmospheric moisture in the condenser tube."

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[1] *Proceedings*, Am. Soc. Testing Mats. Vol 23, Part I, p. 690 (1923).

[2] *Ibid.*, p. 694.

This in no way affects the method and is added to prevent condensation of atmospheric moisture in the upper part of the condenser tube.

(*c*) Tentative Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge (D 96 – 21 T)[1] with a change in the temperature of bath specified in Section 6 (*a*) from 100° F. to 120° F. This change is made in order to insure complete solution of bituminous materials in the solvent used. Fig. 1 in the method has been changed as is indicated in the report of Sub-Committee XVI on Water and Sediment, eliminating the dimensions and correcting the proportions.

Appended hereto are reports of the following sub-committees: I, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XVI, XVII, XVIII, XIX, XX, XXI, XXII, XXIII.

The method of test recommended for submission as a tentative standard, the recommended revisions of present tentative standards, the withdrawal of present standards, the advancement of tentative standards to standard have been submitted to letter ballot of the committee, which consists of 75 members; 48 ballots have been returned, and 27 members have refrained from voting. The result of the letter ballot is as follows:

Item	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE STANDARD			
Method of Test for Burning Quality of Kerosene Oils	39	4	5
II. PROPOSED REVISION OF EXISTING TENTATIVE STANDARDS			
Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products (D 86 – 23 T)	46	0	2
Method of Test for Melting Point of Petrolatum (D 127 – 22 T)	41	0	7
Method of Analysis of Grease (D 128 – 22 T)	43	0	5
Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 – 23 T)	43	2	3
III. PROPOSED ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T)	47	1	0
Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T)	45	1	2
Tentative Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge (D 96 – 21 T)	45	1	2
IV. WITHDRAWAL OF STANDARDS			
Standard Method of Test for Carbon Residue (Conradson Method) to be withdrawn from present Standard Method of Testing Lubricants (D 47 – 21)	44	2	2
Standard Method of Test for Free Acid in Lubricants to be withdrawn from present Standard Methods of Testing Lubricants (D 47 – 21)	43	0	5

This report has been submitted to letter ballot of the committee, which consists of 75 voting members, of whom 47 have voted affirmatively, none negatively, and 28 have refrained from voting.

Respectfully submitted on behalf of the committee,

VAN. H. MANNING,
Secretary.

C. P. VAN GUNDY,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 670 (1921).

EDITORIAL NOTE

The Tentative Method of Test for Flash and Fire Points by Means of Open Cup, the Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials and the Tentative Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge, amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products, the Method of Test for Melting Point of Petrolatum, the Method of Analysis of Grease, the Method of Test for Viscosity of Petroleum Products and Lubricants and the Method of Test for Sulfur in Naphthas and Illuminating Oils, recommended in this report, were approved at the annual meeting. The methods, as thus revised, appear on pages 864–887 and 894.

The proposed Tentative Method of Test for Burning Quality of Kerosene Oils, referred to in this report, was accepted for publication as tentative and appears on page 888.

The withdrawal of the Standard Method of Test for Carbon Residue and of the Standard Method of Test for Free Acid in Lubricants from the Standard Methods of Testing Lubricants, as recommended in this report, was approved. The methods were accepted for publication as tentative and appear on pages 898–901.

REPORT OF SUB-COMMITTEE I ON PETROLATUM

The active work of the sub-committee during the past year has been confined to checking up the readings of the Tentative Method of Test for Melting Point of Petrolatum (D 127 - 22 T),[1] with the methods formerly in common use. Its workability and reproducibility have been confirmed. The duration of the test has been shortened by cooling the coating on the thermometer bulb in tap water instead of in air, which is covered by a slight change in Section 5 (*a*), making the last sentence read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> "It shall be withdrawn immediately, held vertically away from the heat until the surface dulls, and [suspended at a temperature of not over 80° F. for 60 minutes] *then placed in a water bath having a temperature not over 60° F. for five minutes.*"

Cooperative tests will be made during the coming year to learn whether or not consistent results will be obtained if the water-bath temperature be raised more rapidly up to 100° F. in the hope of still further reducing the time.

No study has yet been made of a method for determining the consistency or plasticity of petrolatum. This characteristic is so closely related to the same test for lubricating greases that it is believed the same method can be applied to both. The Sub-Committee on Grease, under the chairmanship of Mr. Robert E. Wilson, has investigated various devices, and has concluded that the regular asphalt penetrometer, with a special cone-shaped "needle," performs so well as to give promise of its being adopted as a standard device. The approved form of this "needle" is a 45-deg. angle cone, and is interchangeable with the needle used in testing asphalt. The spring, however, should be a little stronger than for testing asphalt. The cone-shaped needle is made of polished brass with a hardened steel tip blunted to a diameter of 0.5 mm. (0.02 in.), the total weight of the plunger plus the cone being 150 g.

The detail of first heating the petrolatum to a temperature of 180° F. (82° C.) to insure complete solution, with subsequent cooling in a definite manner, will probably have to be observed, which will introduce one practice that is unnecessary in measuring the consistency of greases. The petrolatum may be allowed to cool in 4-oz. low-form ointment jars, approximately $2\frac{1}{4}$ in. in inside diameter and

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 766 (1922).

2 in. deep. The melted material is poured into the jars until level full. It may be found desirable to place the jars in a water bath or on a hot plate heated to at least 120° F. (49° C.) before filling. The source of heat is then removed; the material is cooled gradually to room temperature, and then held in a water bath for two hours at a temperature within 1° F. of 77° F. (25° C.). A thermometer with bulb immersed about ½ in. below the surface of the grease may be used to indicate the proper temperature. A jar of grease is removed to the stand of the penetrometer, and tested as prescribed in the report of the Sub-Committee on Grease for 1923,[1] as follows:

> "The cone is then lowered until the tip just touches the surface of the grease, the scale set, and the plunger released for five seconds. The penetration is read in tenths of a millimeter by the same procedure as is customary in the case of asphalt tests."

Work on consistency will be carried on during the next few months.

Respectfully submitted on behalf of the sub-committee,

FLORUS R. BAXTER,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 349 (1923).

REPORT OF SUB-COMMITTEE III ON PARAFFIN WAX

At an informal meeting of Sub-Committee III held at Washington, D. C., on November 8, 1923, a general discussion of the oil and moisture test on wax took place. Majority opinion at the meeting favored the old press method or a simple modification thereof. A suggestion was made from the floor that paper disks of some sort be used in place of the customary linen or cotton disks. The Solvent Index Method devised by R. E. Wilson was also offered for consideration. It was finally agreed that a new set of sub-committee samples should be prepared and sent to all members for check tests by the method published for information on page 422 of Part I, Volume 22 of the Proceedings of the Society.

To secure data on the behavior of paper disks in place of linen disks in the press method, samples were procured from various paper manufacturers. In all, some fifty samples were received of which but five appeared of possible use. In routine tests with these papers it was found that wax penetrated in every case. After this experience, use of paper in the press method was not considered further.

When the sub-committee samples for check tests were made up, account was taken of the unsatisfactory results obtained from samples prepared by addition of known amounts of pressed oil to samples of hard wax. This time a large quantity of fully refined wax was selected and a set of samples designated as "A" made up. A portion of the primary sample was melted down and 2 per cent by weight of slack wax added. Samples made up were designated "B." A second portion of the primary sample was melted down and 4 per cent by weight of slack wax added. These samples were designated "C." A set of the above samples was sent to each member of the sub-committee with the request that they be tested by the press method.

Reports giving results of tests on the sub-committee samples were received from most of the members. In practically every case individual members reported that no oil could be pressed from any of the samples when the proposed press method was used. At a meeting of the sub-committee held the day preceding the spring meeting of the main committee the results of the work were discussed and the opinion of the sub-committee obtained. By unanimous vote it was agreed that the press method as a possible standard for oil and moisture in wax should be dropped.

As to the direction in which future work of the sub-committee is to lead, members favored a careful study of the Solvent Index Method proposed by R. E. Wilson. Accordingly, it was agreed that individual members would apply the method to his own products and submit a report covering his findings. If success is had with samples of known origin it will then be in order to prepare a new set of sub-committee samples for check tests by all members of the sub-committee.

Respectfully submitted on behalf of the sub-committee,

E. B. PHILLIPS,
Chairman.

REPORT OF SUB-COMMITTEE IV ON GREASE

Work on Consistency Test

The Sub-Committee on Grease has, during the past year, concentrated on the problem of perfecting the cone penetration test for the original consistency of grease, working along the lines mentioned in the last annual report. During the fall, comparative tests were made on five samples of grease by eleven members of the sub-committee. The method used was substantially that described at the end of this report and the results of the tests are shown in Table I.

A study of these results indicates that on the whole the agreement between successive measurements in the same laboratory and between different laboratories is quite satisfactory, especially since none of the operators were familiar with the tests and the exact construction and finish of the cone was not specified as closely as has since been found desirable. It should also be kept in mind that the tests were made over a considerable period of time and after the samples had been shipped long distances in rather fragile containers.

In analyzing these results it was noted that some laboratories tended to get high results on all samples, and others low. Table II was therefore prepared in which each member's results are expressed as a percentage of the average penetration in each sample. It will be noted that in general the deviations of a given laboratory tend to be consistent in one direction or the other. It is also probably significant that the tests which were made first (those in the chairman's laboratory) averaged lowest, while the last two sets of results to be received (Laboratories Nos. 10 and 11), about two months later, gave the highest average. Since the samples were sent out very soon after being made, it rather appears that a considerable proportion of the observed deviations may have been due to actual changes in the grease with the time of standing.

Another possible reason for the low results obtained in the chairman's laboratory was that all the good cones were sent out to other laboratories for the tests, and the results reported were obtained on a cone with a rather rough aluminum surface. In order to see if this was a cause of low results, the very smooth cone used by Laboratory No. 4 was compared with the chairman's on six different samples of grease. The smooth cone gave results averaging 3.75 per cent higher, thus indicating the importance of surface finish and accounting for some of the observed deviation. A very smooth finish on the cones is therefore specified in the proposed method.

TABLE I.—RESULTS OF PENETRATION TESTS ON GREASE SAMPLES.

Laboratory	No. 2 Cup, Grease A		No. 3 Cup, Grease B		No. 4 Cup, Grease C		No. 5 Cup, Grease D		Hard R. R., Grease E	
	Average Penetration	Mean Deviation, per cent	Average Penetration	Mean Deviation, per cent	Average Penetration	Mean Deviation, per cent	Average Penetration	Mean Deviation, per cent	Average Penetration	Mean Deviation, per cent
No. 1	239	1.0	172	1.5	83	1.8	59	3.0	46	0.5
No. 2	254	5.5	170	2.2	85	2.7	66	2.4	51	1.8
No. 3	260	3.6	166	1.5	84	4.8	61	5.1	46	10.0
No. 4	264	0.8	189	0.7	98	2.5	69	2.8	49.7	3.0
No. 5	265	1.8	188	2.8	87	3.5	64	4.1	28.6[a]	2.0
No. 6	245	3.2	184	4.1	97	6.5	68	6.1	50.6	1.8
No. 7	261	2.8	171	4.2	85	5.7	58	7.8	50	....
No. 8	253	2.6	180	2.3	95	2.6	62	6.9	45	1.5
No. 9	248	2.6	175	1.5	61[a]	2.4	71	2.1	19[a]	1.0
No. 10	260	3.8	182	3.2	101	3.0	78	8.1	17.4[a]	....
No. 11	266	2.5	193	1.5	100	1.2	70	2.3	53	1.3
Average	256	2.8	179	2.3	92	3.4	67	4.6	49	2.9
Average deviation between laboratories, per cent	...	2.8	...	4.2	...	7.3	..	7.2	..	5.1

[a] Not included in averages on account of deviation from directions.

TABLE II.—RESULTS REPORTED AS A PERCENTAGE OF THE AVERAGE.

LABORATORY	GREASE A, PER CENT	GREASE B, PER CENT	GREASE C, PER CENT	GREASE D, PER CENT	GREASE E, PER CENT	AVERAGE
No. 1	90	96	90	88	94	92
No. 2	99	95	92	99	104	98
No. 3	101	93	91	91	94	94
No. 4	103	106	106	103	101	104
No. 5	103	105	95	96	...	100
No. 6	96	103	105	101	101	101
No. 7	102	96	92	87	102	96
No. 8	99	100	103	93	92	97
No. 9	97	98	...	106	...	100
No. 10	101	102	110	116	...	107
No. 11	104	108	109	104	108	107

Various tests were also made to determine the effect of the temperature of the cone on the observed penetration, and it was found that if the grease was at 77° F. (25° C.) a variation of the cone temperature from 70 to 90° F. (21 to 32° C.) made less than 2 per cent difference in the result obtained. It is therefore felt that within ordinary limits of room temperature, the cone temperature need not be controlled.

Further tests were also made on the rate of heating which indicated that if a covered one-pound can of grease was immersed in water at 77° F. (25° C.) it could be brought from 60° F. (16° C.) to within 1° of 77° F. (25° C.) in $1\frac{1}{2}$ hours.

In connection with this method it is also of interest to give the comparative consistencies obtained by this method on commercial cup greases from ten different manufacturers. These are given in Table III.

In the light of the experience thus far obtained it is believed that the test as described at the end of this report will give entirely satisfactory check results. However, during the winter, comments on the proposed test were requested from various interested parties and vigorous objections were expressed in certain quarters to standardizing a test on the original or unworked consistency of grease without any method of testing the consistency *under the conditions of use* which involve working, and without any information as to the relationship between the two tests. It was also pointed out that certain greases have a "false body" which breaks down quickly under working, and that such greases would be given an unfair advantage by the proposed method of test. A canvass of the committee in the light of these objections showed that the great majority favored the publication of the proposed method of test for information only, pending a study of questions raised by these objections. It has, however, been put in the form of a tentative standard and is appended hereto as information.

TABLE III.—COMPARISON OF DIFFERENT BRANDS OF GREASE TESTED IN ORIGINAL CONTAINERS.

	Penetrations					
MANUFACTURER	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
A	380	264	185	76	67	..
B	...	...	123	..	..	..
C	...	208	150	87	42	..
D	...	340	187	..	47	..
E	390	276	162	72	64	..
F	256	...	181	..	111	..
G	235	...	130	..	93	..
H	366	208	114	89	54	31
I	...	240	130	..	..	..
J	276	...	119	..	55	..
Average	317	256	148	81	66	31

During the coming year the committee therefore plans to focus its attention on the problem of developing some simple and reproducible method of working the grease before making the consistency test, and then to find what relationship, if any, exists between the two tests.

MODIFICATION OF METHOD FOR GREASE ANALYSIS

The Tentative Method of Analysis of Grease, submitted in 1922, has on the whole given very satisfactory results, but a canvass of the committee indicated that, if the method were followed rigidly, three difficulties were frequently encountered, as follows:

1. When the sample is dissolved with HCl in a beaker in the presence of petroleum ether, there is a tendency to lose fatty acid due to crawling. This also occurs to some extent when evaporating petroleum ether solutions of fatty acid unless special precautions are taken.

2. The specified method of removing solvent from the fatty acid by heating at 120° C. for one hour results in loss of fatty acid.

3. A small proportion of the fatty acids are not soluble in petroleum ether and this solvent tends to form troublesome emulsions. It was selected as the solvent because ethyl ether, a better solvent, dissolves a small amount of oxidized fatty acids which discolors the final product and makes the identification of the individual acids difficult.

It also developed that three laboratories had been using with entire success very similar slight modifications of the method to overcome these objections, and it was therefore recommended by the committee that the following changes be made in the Tentative Method of Analysis of Grease (D 128 – 22 T):[1]

Section 15.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> "[The sample shall be weighed in a small beaker (see Section 2), 75 cc. of petroleum ether and] *If no fillers are present, Sections 15 and 16 shall be passed over and the grease sample introduced directly from a weighing bottle into a separator, the weight of the sample being obtained by difference.* (*See Section 2.*) *The sample shall then be shaken with 75 cc. of petroleum ether and 50 cc. of 10-per-cent hydrochloric acid until the grease is completely decomposed, after which Section 17 shall be followed. If fillers are present, the sample* (*See Section 2*) *shall be weighed in a small beaker*, 50 cc. of 10-per-cent hydrochloric acid added and the beaker warmed on the steam bath, stirring until all soap lumps have disappeared and the upper layer is clear.

Section 17.—Change the first sentence to read as follows by the addition of the italicized words:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 768 (1922).

"*The solutions resulting from the decomposition of the filler-free grease or* the combined filtrate and washes from the determination of fillers (Section 15), except the alcohol, which is discarded, shall be placed in a separator, allowed to clear, and the aqueous layer (A), which contains all the bases as well as glycerin, shall be drawn into another separator."

Change the thirteenth sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

"Solution (D) shall then be evaporated to a small volume to remove alcohol, the residue of potassium soap washed into a separator with hot water, acidified with hydrochloric acid and shaken out [three times, with 50, 30 and 20 cc. of petroleum ether] *twice with 50 and 25 cc. of ethyl ether* (F), respectively."

Change the sixteenth sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

"The residue consisting of free fatty acid and fatty acid from soap shall be heated [one hour at 120° C.] *for a short time on a steam bath, adding and evaporating 5 cc. of absolute alcohol to remove the last traces of water,* and weighed."

At the end of Section 17, add a paragraph to read as follows:

"If the grease is appreciably oxidized, the fatty acids obtained by the ethyl ether extraction are likely to be dark in color and hard to identify. For further study and identification, the neutralized acids may be extracted again (qualitatively) with petroleum ether and dilute HCl, thus eliminating the small amount of more darkly colored matter."

Figure 1.—Under alcoholic solution (D) change "Shake out 3 times with P. E." to read: "Shake out twice with EtO"; Change "P. E. Sol'n = (F)" to read: "EtO Sol'n = (F)" in both places where it appears. Under notes, add after "P. E. = Petroleum Ether," "EtO = Ethyl Ether."

Respectfully submitted on behalf of the sub-committee,

R. E. WILSON,
Chairman.

APPENDIX

PROPOSED METHOD OF TEST FOR THE PENETRATION OF CUP AND RAILROAD GREASES

1. *Scope.*—This method shall be used to measure the original consistency of cup greases Nos. 2 to 5, inclusive, and of other greases which give a penetration between 300 and 40 (measured in tenths of a millimeter).

2. A modification of this method shall be used to test harder greases such as railroad greases which give a penetration lower than 40 on the regular method.

3. The method should be applied only to greases which have not been worked or melted after having been poured and cooled during manufacture.

FIG. 1.—Penetrometer.

I. APPARATUS

4. *Penetrometer.*—The penetration shall be measured on what is customarily known as an asphalt penetrometer such as that shown in Fig. 1. It is desirable, however, to modify this penetrometer in two respects as follows:

(*a*) A flat metal plate or transite board should be placed on top of the present grid base to give a flat support for the grease can. If many tests are to be made, it is preferable to replace the ordinary grid base with a special flat base 6 in. in diameter, such as is shown in Fig. 1. This plate should have a cork insert in the center to prevent dulling the tip of the cone if it should drop.

(*b*) The spring which prevents release of the plunger may not be strong enough to hold the 450-g. weight used on the hard railroad greases, and if many such tests are to be made it is desirable to replace the spring with a stiffer one or increase its compression by placing a small object behind it.

5. *Cone and Plunger.*—The plunger and needle used in the asphalt penetration tests shall be replaced with a combined cone and plunger as shown in Fig. 2. The cone shall be constructed of stainless steel or of brass with a hardened steel or stainless steel tip, and made according to the dimensions shown. The outside surface of the cone and tip shall be given a very smooth finish. The plunger should preferably be made from a hollow tube so that the cone will not need to be hollowed out excessively to give the desired weight.

6. *Weight.*—The weight of the cone plus the plunger shall be 150 g. for cup greases Nos. 2 to 5, inclusive, and for other greases which give a penetration between 300 and 40. If the conditions of the tests are not specified, the penetration of a grease shall be understood to refer to this test with the 150-g. weight at 77° F. (25° C.). For hard greases giving a penetration below 40 on the regular test, an additional weight of 300 g. shall be added on top of the cone, making a total weight of 450 g. These penetrations shall always be referred to as 450-g. penetrations.

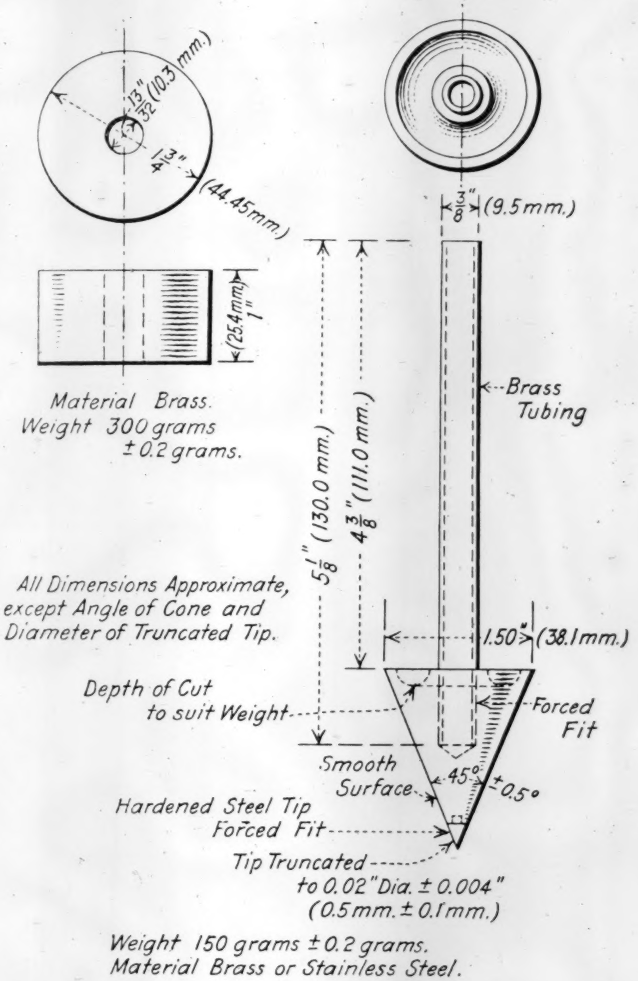
13"/32 (10.3 mm.)
1 3/4" (44.45 mm.)
(25.4 mm.) 1"
Material Brass.
Weight 300 grams ± 0.2 grams.
3/8" (9.5 mm.)
5 1/8" (130.0 mm.)
4 3/8" (111.0 mm.)
Brass Tubing
All Dimensions Approximate, except Angle of Cone and Diameter of Truncated Tip.
1.50" (38.1 mm.)
Depth of Cut to suit Weight
Forced Fit
Smooth Surface
45° ± 0.5°
Hardened Steel Tip Forced Fit
Tip Truncated to 0.02" Dia. ± 0.004" (0.5 mm. ± 0.1 mm.)
Weight 150 grams ± 0.2 grams.
Material Brass or Stainless Steel.

FIG. 2.—Cone for Grease Penetrometer.

7. *Constant Temperature Bath.*—A constant temperature bath regulated to 77° F. ± 1° F. (25° C. ± 0. 5° C.) is desirable to bring the samples to the temperature of test if many tests are to be made.

II. SAMPLES

8. *Test in Original Container.*—When possible the tests shall be made in the original container, one-pound tins being especially convenient for the purpose. If samples are to be taken from large containers, care must be taken not to "work" them appreciably.

9. *Sampling from Larger Container.*—A suitable method of sampling from a large container is to punch several holes in the bottom of a one-pound grease tin and force it, top down, into the grease until it is full. Then cut off the grease at the top of the can with a curved knife. The surface should later be cut off smooth and level with an ordinary knife. Care must be taken that the can is completely filled, otherwise the entire mass of grease may move when the plunger is released.

III. PROCEDURE

10. *Bringing to Temperature of Test.*—The temperature of a sample shall be brought to within 1° of 77° F. (25° C.) before the test. If the sample is initially within 3 or 4° of this temperature, it can be brought to 77° F. (25° C.) by placing in a water bath for 30 or 40 minutes, but if the initial temperature is outside this range it must be placed in the constant temperature bath for 1½ hours to insure reaching the final constant temperature. If the room temperature is more than 3 or 4° from 77° F. (25° C.) a lid should be placed on the can, sealing with grease to prevent the entrance of water and immersing in the bath for the required period as, otherwise, the temperature of the surface will be different from that of the main body of the grease. Any holes or seams in the can should also be sealed with grease or paraffin.

11. *Preparation of Sample.*—The surface of the grease shall be cut smooth and level with a knife. Care must be taken not to work the surface of the grease. Any crust or discolored surface shall be removed before testing.

12. *Procedure.*—The can of grease shall be placed on the penetrometer table and the cone lowered until the tip just touches the surface. The scale shall then be set to zero and the plunger released *suddenly* and kept released for five seconds. The penetration is read from the scale (the units being tenths of a millimeter) by the same procedure as is customary in measuring asphalt penetrations. (See Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5) of the American Society for Testing Materials.[1])

13. *Spacing of Tests in Cans.*—In making tests the total surface area disturbed by the test has a diameter about equal to the measured depth of penetration. In order to prevent one test from being affected by another disturbed area or by sides of the can, in starting a test the tip shall never be placed closer to the sides of the can or the edge of a previous hole than the penetration distance of that particular grease.

14. *Number of Tests Required.*—Five tests shall be made on each sample and the average reported as the consistency, if the mean deviation of these readings does not exceed 3.0 per cent. If the mean deviation does exceed 3.0 per cent, the average of ten readings shall be reported as the consistency of the sample.

IV. INTERPRETATION OF RESULTS

15. *Interpretation of Results.*—It should be understood that the original consistency of grease is determined by a variety of factors which are very difficult to control. The soap content is the most important single factor, but the kind of fats

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[1] 1921 Book of A.S.T.M. Standards.

used, the method of mixing, the final water content, and the temperature of pouring are all very important in determining the final consistency, so that it is impracticable to maintain these consistencies within narrow limits. Any working of the sample after it is poured, or any remelting, will greatly change the consistency. The consistency also changes to some extent on standing, most rapidly during the first 48 hours after manufacture and more slowly thereafter.

Attention should also be called to the fact that the original consistency of the grease does not necessarily bear any relationship to its consistency in use when it has been worked very thoroughly. The development of a test for the latter property is now under consideration by the committee.

REPORT OF SUB-COMMITTEE V ON VISCOSITY

The following changes are recommended in the Tentative Methods of Test for Viscosity of Petroleum Products and Lubricants (D 88 - 23 T):[1]

Table I.—Add to the table of dimensions the following requirement:

"Outside diameter of overflow rim, at the top, not over 3.30 cm., maximum.[a]

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[a] The minimum value shall preferably be not less than 3.2 cm.

Add to Table I:

"The section of overflow rim must show a straight line from the outside of rim at top to the bottom of gallery."

Section 2.—After the third sentence insert two sentences to read as follows:

"The outlet tube is of hard and non-corrosive metal such as stainless steel, monel metal, etc. The inside diameter of neck of flask, at the level where the graduation mark is placed, is 0.8 to 1.1 cm."

In the next to the last sentence of Paragraph (*a*) change "60-mesh wire strainer" to read "100-mesh wire strainer."

Add a sentence to Paragraph (*b*) to read as follows:

"The time of flow shall be within ± 1 per cent of the time as obtained with the Bureau of Standards' master tube."[b]

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[b] This tube represents the average mechanically perfect tube, based on the A.S.T.M. specifications, and has been approved by the American Petroleum Institute Committee on Viscosity Standards.

In the table of requirements for thermometers add a sentence under "standardization" to read as follows:

"Correction for emergent stem shall not be applied."

Section 4.—Change the first paragraph from its present form: namely,

"The bath shall be held constant within 0.25° F. (0.14° C.) at such a temperature as will maintain the desired temperature in the oil tube. For viscosity determinations at 100, 122 and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at 210° F., oil shall be used as the bath liquid. Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the oil tube either for cleaning or for test shall first be passed through the strainer."

to read as follows:

"Throughout the test the bath temperature shall not vary more than ± 0.1° F. (0.06° C.) from the predetermined temperature which will maintain thermal equilibrium until the oil tube thermometer is withdrawn. Water shall be used as the bath liquid at all temperatures.[c]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 672 (1923).

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[c] In ordinary routine testing it is frequently desirable to employ oil as a bath medium instead of water. This is allowable provided the temperature of the oil bath is adjusted so that the necessary condition of thermal equilibrium is maintained. It is usually necessary to maintain the oil bath at slightly higher temperatures than are necessary when water is the bath medium. Oil bath temperatures will need to be from 0.1 to 0.2° F. (0.06 to 0.11° C.) higher for tests at 100° F. (37.8° C.) and from 1.5 to 2.0° F. (0.83 to 1.11° C.) higher for tests at 210° F. (98.9° C.) than the corresponding water bath temperatures.

"Any construction of bath may be employed provided the bath temperature necessary to maintain thermal equilibrium (while the oil in the oil tube is well stirred by the oil tube thermometer) is not in excess of 100.25, 122.35, 130.50 and 212.00° F. (37.9, 50.2, 54.7 and 100.0° C.), respectively, for the standard temperatures previously mentioned. The level of the bath liquid shall not be lower than 0.5 cm. above the overflow rim of the oil tube. The heating and stirring of the water bath for the determination of viscosity at 210° F. (98.9° C.) shall be accomplished by the direct injection of steam near the bottom of the bath. The heating and stirring of the bath for other temperatures may be accomplished by any suitable means, provided the source of heat is not less than the following distances from any part of the oil tube: 2 in. (5 cm.) with an external heater, 1¼ in. (3 cm.) with an immersion heater. Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. The room temperature shall be between 68 and 86° F. (20 and 30° C.).[d] All oil introduced into the oil tube either for cleaning or for test shall first be passed through the strainer."

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[d] These limits are necessary for extreme accuracy in standardization and referee tests, but for routine purposes the use of higher temperatures up to 100° F. (37.8° C.) will not ordinarily cause an error of more than 1 per cent.

Change the first sentence of the third paragraph to read as follows by the addition of the italicized words and figures and the omission of the word in brackets:

"Heat the oil to be tested, outside the viscosimeter, to slightly [below], *but not more than 3° F. (1.7° C.) above* the temperature at which the viscosity is to be determined, and pour it into the oil tube until it ceases to overflow into the overflow cup."

Add a paragraph to read as follows:

"With proper attention to details of method of procedure, duplicate results should not differ from each other by more than 1 per cent."

Insert under the figure showing the flask the words:

"This type of flask is recommended as convenient and durable."

The sub-committee recommends that the tentative methods, as revised, be continued as tentative.

Respectfully submitted on behalf of the sub-committee,

WINSLOW H. HERSCHEL,
Chairman.

REPORT OF SUB-COMMITTEE VI ON COLOR

Considerable work and experimenting with an artificial source of light for the Union Colorimeter and Saybolt Chromometer was carried out, but no definite conclusions and results have been reached.

The U. S. Bureau of Standards was asked to cooperate on this subject, particularly as to the spectro-analysis of light produced by the *C2* Mazda lamp in conjunction with a color screen, which will yield a light closely approximating northern daylight.

The color disk standards for the Union Colorimeter as well as for the Saybolt Chromometer are at present subjects of study and the H. V. Arny scheme of making up permanent color standards using cobalt chloride, ferric chloride and cupric sulfate is under study.

The standardization of the Saybolt Chromometer color disks is well under way, and the members of the sub-committee have been requested to try solutions of $K_2Cr_2O_7$ for checking up the colors of the disks. From replies and comments so far received, this method offers possibilities and may prove very satisfactory.

The sub-committee is not offering any changes in its tentative standards and recommends that they be continued as tentative.

Respectfully submitted on behalf of the sub-committee,

I. K. Giles,
Chairman.

REPORT OF SUB-COMMITTEE VII ON SULFUR DETERMINATION AND DIFFERENTIATION

In view of the fact that Sub-Committee XVII on Gasoline had decided to take up the copper strip test for the detection of elementary and corrosive sulfur compounds, Sub-Committee VII dropped the work it had been doing on this subject. Due to the adoption by the Federal Specifications Board of a limit of 0.1 per cent of sulfur in motor gasoline, and the wide acceptance of Federal specifications by states and communities, the sub-committee felt it would be desirable to investigate the reliability of the lamp method for the determination of sulfur, the Tentative Method of Test for Sulfur in Naphthas and Illuminating Oils (D 90 - 21 T). Experience with this method as applied to illuminating oils led to the belief that some difficulties might arise in extending its application to gasoline. Three samples were accordingly sent to each member of the committee: (1) a sample of Mexican naphtha; (2) a sample of motor gasoline; and (3) a sample of light naphtha used in the determination of precipitation number. The results reported to date are as follows:

Laboratory Number	Sample No. 1	Sample No. 2	Sample No. 3
No. 1..........	0.180 per cent	0.019 per cent	0.035 per cent
No. 2........	0.187 " "	0.028 " "	0.034 " "
	0.189 " "	0.024 " "	0.034 " "
Average........	0.188 " "	0.026 " "	0.034 " "
No. 3........	0.185 " "	0.015 " "	0.031 " "
	0.183 " "	0.015 " "	0.033 " "
	0.187 " "	0.017 " "	0.031 " "
Average........	0.185 " "	0.016 " "	0.032 " "
No. 4	0.190 " "	0.019 " "	0.040 " "
	0.189 " "	0.019 " "	0.037 " "
	0.192 " "	0.020 " "	0.038 " "
Average........	0.190 " "	0.019 " "	0.038 " "
No. 5........	0.182 " "	0.021 " "	0.036 " "
	0.183 " "	0.020 " "	0.034 " "
	0.186 " "	0.021 " "	0.036 " "
Average........	0.184 " "	0.021 " "	0.035 " "

The committee recommends the following revision of the Tentative Method of Test for Sulfur in Naphthas and Illuminating Oils (D 90 - 21 T)[1]:

Add a paragraph on scope to read as follows:

"This method is intended to be applied to illuminating oils and petroleum naphthas. It is not applicable to mixtures containing carbon bisulfide.

The committee further recommends that with this revision, the method be continued as tentative.

Respectfully submitted on behalf of the sub-committee,

N. A. C. SMITH,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 644 (1921).

REPORT OF SUB-COMMITTEE VIII ON DISTILLATION

Sub-Committee VIII has considered and approved a revision of the specifications for the low- and high-distillation thermometers, as proposed by Committee D-15 on Thermometers. It was recommended that the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products (D 86 - 23 T)[1] be revised by replacing the present thermometer specifications by those appended to the Report of Committee D-15 on Thermometers for low- and high-distillation thermometers,[2] and that the tentative method, as revised, be continued as a tentative standard.

The sub-committee is endeavoring to work up a table for correcting distillation results for differences in barometric pressure. Some progress has been made, but it is desired to obtain further experimental evidence before a table is decided upon.

Respectfully submitted on behalf of the sub-committee,

Ernest W. Dean,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 665 (1923).

[2] See pp. 691–694.—Ed.

REPORT OF SUB-COMMITTEE IX ON PRECIPITATION

Due to the death of Mr. W. C. Marckworth, the chairmanship of this sub-committee has been changed.

Before summarizing the work of this sub-committee for the past two years it may be stated that the results obtained by the present Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 – 21 T), were not as reproducible as desired. It seems that various grades of naphtha produced from crudes in different sections of the country, although complying with the requirements of the method, exerted a different solvent effect upon the asphaltic constituents of the oil. The physical properties of the precipitate from various oils also differed quite widely, especially in regard to density and color.

To possibly overcome this latter point a gravimetric method consisting of weighing the precipitated matter on a Gooch crucible was proposed. Samples of the various oils were sent to the members of the sub-committee to determine the value of the gravimetric method. The diluent, furnished by one member, was used by all the laboratories. Results of this work did not show the accuracy desired, and the reasons therefore have not been satisfactorily explained. It would have been of value, no doubt, to have tested the same oils with the same diluent using the volumetric method as written. This, however, was not done.

The future work of the committee is to investigate the properties of various grades of naphtha, made according to the requirements of Method D 91 in different sections of the United States. These samples will also be comparatively examined as to their precipitating action using the volumetric method as written, and also a gravimetric method. Experiments will also be made with the volumetric method varying the proportion of oil and diluent. It has been thought that the naphtha as prescribed in Method D 91 is not specified sufficiently rigidly, and that a product known as "Normal Benzine," described by Holde,[1] having a closer boiling range (65 to 95° C.) might be more suitable, and comparative tests will also be made with a naphtha prepared according to these specifications.

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[1] "The Examination of Hydrocarbon Oils," fifth German Edition, p. 186; Also English translation by Edward Mueller.

The use of a diluent other than a light gasoline would be quite desirable as this would eliminate the evident source of error caused by diluents prepared from different crudes. Various organic liquids or mixtures of them have been tried, but up to the present time none has been found to be entirely satisfactory.

Respectfully submitted on behalf of the sub-committee,

P. A. CROSBY,
Chairman.

REPORT OF SUB-COMMITTEE X ON OXIDATION AT HIGH TEMPERATURES

The sub-committee has under consideration a method for conducting an oxidation test on lubricating oils recently developed at the U. S. Bureau of Standards.

The method consists in exposing a sample of the lubricating oil in a closed standard flask filled with oxygen to a temperature of 200° C. (immersion in a well-stirred oil bath at this temperature) for 2½ hours. The mass of precipitate thrown out by a definite solution of the oxidized sample in petroleum ether is determined. The mass of this precipitate, expressed as a percentage of the mass of the original sample (10 g.), is taken as the oxidation value of that sample.

The individual members of this committee have agreed to set up the required apparatus and, working on similar samples of motor lubricating stocks, to investigate the constancy and reproducibility of the method.

Progress on this cooperative work is as good as could be hoped for and it is believed that the proposed tests will yield definite information regarding the feasibility of the method.

The method, as handled at the Bureau of Standards, has given consistently reproducible results on a variety of lubricating oils. Oxidation work is being continued there to provide information regarding the effects of variations in test conditions and the relations which may possibly exist between oxidation value and other characteristics of the lubricant.

Attention is specially called to the fact that the proposed method is now under consideration as a measure of the stability of a petroleum lubricating oil in contact with oxygen at the test temperature. If its suitability is proved, the question of correlation between oxidation values and service or engine tests of lubricants will be taken up.

Respectfully submitted on behalf of the sub-committee,

W. S. James,
Chairman.

REPORT OF SUB-COMMITTEE XI ON EMULSIFICATION

In March, 1923, acting on the recommendation of Sub-Committee XI, Committee D-2 as a whole decided to concentrate work on the R. E. Emulsion Test for referee purposes and on the basis of results obtained, this test was published as a tentative standard as the Tentative Method of Test for Steam Emulsion of Lubricating Oils (D 157 - 23 T). Several minor modifications were made in the R. E. Emulsion Test to simplify manipulation of the test before submitting it as a tentative standard.

During the past year the work of the sub-committee has been devoted to:

1. A further study of the A.S.T.M. Steam Emulsion Test.
2. An investigation of the Surface Tension Emulsion Test developed by Mr. H. Dimmig, of the Texas Company.[1]
3. An investigation of the Sinclair Emulsion Test developed by Mr. E. B. Phillips, of the Sinclair Refining Co.

A description of the Surface Tension Emulsion Test is given in the 1923 report of Committee D-2[1] and the Sinclair Emulsion Test is described in the Appendix to this report.

A series of nine oils, furnished by members of the sub-committee, were sent to each of the committee members to be examined by the above tests. A questionnaire was also sent out by the chairman to get a definite statement of the opinion of the sub-committee members of the value of these tests in testing the different classes of oils.

The results of the tests on the nine oils are given in Tables I, II, and III.

DISCUSSION OF RESULTS AND A BRIEF SUMMARY OF ANSWERS TO THE CHAIRMAN'S QUESTIONNAIRE

A. Steam Emulsion Test

The results obtained on the steam emulsion test show a very satisfactory agreement on all oils except No. 3T. This oil has a high viscosity and the rather poor agreement of results is due to the fact that certain types of high-viscosity oils separate from water in a different manner than low-viscosity oils and some difficulty is encountered in maintaining all the requirements of the test as to steaming temperature and time. Good check results on high-vis-

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[1] Howard Dimmig, "Method of Measuring the Emulsifying Tendency of Lubricating Oils, Based on Surface Tension," *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 363 (1923).

TABLE I.—STEAM EMULSION TEST, R. E. NUMBERS.

LABORATORY	OIL 1T	OIL 2T	OIL 3T	OIL SA	OIL SB	OIL SC	OIL A1	OIL A2	OIL A3
No. 1	1.5	1.5	16.0	1.0	1.5	4.5	20+	11.5	3.0
	1.5	1.5	16.0	1.0	2.0	5.0	20+	11.5	3.5
No. 2	1.5	1.0	20.0	0.5	1.5	5.0	20+	12.0	3.0
No. 3	1.0	1.5	18.5	...	...	...	....	....	...
No. 4	1.5	1.5	14.5	1.0	1.5	5.0	17.5	12.5	3.5
No. 5	1.5	1.0	20+	1.5	1.5	5.0	20+	11.5	3.0
	1.5	1.0	20+	1.5	1.5	5.0	20+	11.5	3.0
No. 6	1.0	1.0	10.0	1.0	1.0	4.0	20+	11.5	3.5
No. 7	1.5	1.4	20+	1.6	1.8	5.7	20+	11.1	2.8
	1.7	1.5	20+	1.7	1.7	6.2	20+	10.8	2.7
No. 8	1.0	1.0	18.0	1.0	1.5	5.5	20+	12.0	2.5
	1.5	1.0	20.0	1.0	1.5	5.5	20+	12.0	2.5
No. 9	1.5	1.5	13.5	1.5	1.5	4.0	20+	10.0	3.0
	1.5	1.5	14.0	1.0	1.5	4.0	20+	10.0	3.0
No. 10	1.2	1.2	18.9	1.0	1.2	3.9	20+	10.5	3.0
No. 11	1.5	1.5	20.0	1.0	1.5	4.5	20+	13.5	4.0
No. 12	2.0	1.5	14.5	1.5	2.0	7.0	20+	16.5	4.5
	2.0	1.5	14.0	1.5	2.0	6.5	20+	15.5	4.0
No. 13	...	...	....	1.0	1.5	4.0	20+	12.0	3.0
	...	...	....	1.0	1.5	3.0	20+	10.0	4.0
No. 14	1.5	2.0	20.0	1.5	2.5	4.5	20.0	11.0	2.5
	1.5	1.5	20.0	1.5	2.5	4.0	20+	11.5	2.5
No. 15	1.5	2.0	18.0	1.0	1.5	5.0	20+	16.0	3.0
	1.5	2.0	18.0	1.0	1.5	5.0	20+	15.0	3.0
No. 16	2.0	1.5	18.0	1.0	1.5	5.0	20+	18.0	4.0
Average results	1.5	1.5	18.0	1.0	1.5	5.0	20+	12.0	3.5
Approximate Saybolt viscosity at 100° F.	145	295	1355	197	195	219	310	295	285

TABLE II.—SINCLAIR EMULSION TEST.

Laboratory	Oil 1T	Oil 2T	Oil 3T	Oil SA	Oil SB	Oil SC	Oil A1	Oil A2	Oil A3
No. 1	Poor	Medium	Medium	Good	Good	Poor	Poor	Medium	Medium
	Poor	Medium	Medium	Good	Good	Poor	Poor	Medium	Medium
No. 3	Good	Good	Medium	.....	.....	.....	.....	.....	.....
No. 4	Good	Good	Poor	Perfect	Good	Poor	Poor	Poor	Poor
No. 5	Good	Good	Poor	Good	Good	Medium	Poor	Medium	Good
	Good	Good	Poor	Good	Good	Medium	Poor	Medium	Good
No. 6	Good	Good	Medium	Good	Good	Medium	Poor	Medium	Good
No. 7	Medium	Good	Poor	Good	Medium	Poor	Very poor	Poor	Good
No. 10	Good	Good	Medium	Good	Good	Good	Poor	Medium	Good
No. 11	Medium	Good	Poor	Good	Good	Poor	Poor	Medium	Medium
No. 13	.....	.....	.....	Good	Good	Good	Medium	Good	Perfect
	.....	.....	.....	Perfect	Perfect	Good	Poor	Good	Perfect
No. 14	.....	.....	.....	Perfect	Perfect	Perfect	Good	Medium	Perfect
No. 16	Good	Good	Medium	Good	Good	Medium	Poor	Medium	Medium
Average results	Good	Good	Medium	Good	Good	Medium	Poor	Medium	Good

cosity oils can be obtained by noting carefully when the line of demarcation occurs between the upper 20-cc. layer and the rest of the mixture, irrespective of differences in manner of separation.

Several committee members feel that the test could be improved in order to differentiate more sharply in the case of low-viscosity turbine oils which give fairly low R. E. numbers. It is believed that the test itself will permit of much closer readings than one-half minute, as now specified, if these are necessary, and it is suggested that readings be taken corresponding to the exact number of seconds necessary for 20 cc. of oil to separate, reporting results to the nearest one-tenth of a minute. This may be done by taking readings in a transparent settling bath. Preliminary results indicate that checks within one-tenth of a minute can be obtained.

A new method for interpreting the results of tests on turbine oils, in order to take into account the effect of viscosity, has also been proposed. It is suggested that an oil will start off as a good turbine oil if its R. E. number, multiplied by 100 and divided by the Saybolt viscosity at 100° F., yields a figure not greater than 1.5. This method of interpretation for the nine samples is as follows:

	OIL 1T	OIL 2T	OIL 3T	OIL SA	OIL SB	OIL SC	OIL A1	OIL A2	OIL A3
$\frac{100 \times \text{R. E. Number}}{\text{Saybolt viscosity at } 100^\circ \text{ F.}} =$	1.0	0.5	1.3	0.5	0.8	2.3	6.4+	4.1	1.2

The majority of the members are now of the opinion that the R. E. numbers parallel the results obtained in practice with oils to which it has been found desirable to apply an emulsion test.

The following are the average results from the different laboratories in reply to the question, "What do you consider the probable error for R. E. numbers?":

from 0.5 to 2.5	0.5
" 2.5 " 7.5	0.5
" 7.5 " 20.0	1.0

The addition of oleic acid as a means of promoting separation of oils which had an R. E. number of 20 plus, and distinguishing more carefully between such oils, was investigated in the chairman's laboratory and results have been described in the 1923 report of Committee D-2.[1] While giving interesting information, it was the vote of the committee that it was not desirable to differentiate between oils having such a high R. E. number.

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[1] *Proceedings* Am. Soc. Testing Mats., Vol. 23, Part I, p. 358 (1923).

B. Sinclair Test

The agreement between the different laboratories on the Sinclair test was not very satisfactory. This can no doubt be improved by further standardization of the test.

Mr. Phillips is working on the standardization of the vessel to be used and is having made a vertical-wall glass, $2\frac{9}{16}$ in. in diameter and $3\frac{11}{16}$ in. high, with an absolutely flat bottom. He points out that the stirring device must be standardized as to speed, size, shape of disk on spindle, and location of the disk in the test glass.

TABLE III.—TEXAS CO. EMULSION TEST, VALUE OF "K".

$$K = \frac{\text{cubic centimeters per 100 drops in 0.01 } N \text{ caustic}}{\text{cubic centimeters per 100 drops in distilled water}}$$

LABORATORY	OIL 1T	OIL 2T	OIL 3T	OIL SA	OIL SB	OIL SC	OIL A1	OIL A2	OIL A3
No. 1......	0.931	0.965	0.487	0.904	0.971	0.252	0.218	0.719	0.823
	0.928	0.988	0.500	0.920	0.955	0.242	0.222	0.708	0.840
No. 2......	0.967	0.956	0.542	0.979	0.879	0.606	0.299	0.974	0.949
No 3......	0.905	0.945	0.423	.....	.....	.....	.....	.....	.....
No 4......	0.950	0.938	0.343	0.934	0.882	0.316	0.368	0.899	0.932
No. 5[a].....	0.934	0.981	0.388	0.962	0.940	0.391	0.358	0.888	0.929
No. 6......	0.944	0.935	0.426	0.627	0.918	0.287	0.217	0.854	0.941
	0.942	0.930	0.429	0.612	0.918	0.284	0.215	0.851	0.932
No. 7......	0.913	0.927	0.500	0.923	0.917	0.434	0.303	0.785	0.939
	0.926	0.910	0.513	0.919	0.951	0.419	0.314	0.741	0.979
	0.945	0.914	0.470	0.915	0.917	0.443	0.303	0.758	0.968
No. 9......	0.922	0.919	0.447	0.891	0.817	0.391	0.237	0.754	0.791
	0.916	0.898	0.377	0.871	0.874	0.402	0.229	0.804	0.849
No. 11.....	0.946	0.873	0.353	0.968	0.632	0.601	0.618	0.903	0.755
	0.923	0.847	0.408	0.898	0.650	0.632	0.661	0.963	0.806
No. 16.....	0.932	0.964	0.505	0.940	0.939	0.342	0.390	0.877	0.939
	0.905	0.921	0.504	0.944	0.938	0.344	0.379	0.910	0.910
Average results...	0.93	0.93	0.45	0.92	0.92	0.41	0.28	0.82	0.89

[a] The tests made by Laboratory No. 5 were with a pipette constructed at that laboratory.

The general opinion is that this test is not satisfactory for a referee test, due to the fact that the interpretation of results depends too much on personal opinion and the results cannot be expressed numerically. Several members believe the test should be satisfactory for plant control but it is pointed out that the test takes a comparatively long time to run (one hour). Several laboratories are able to obtain reproducible results when the same operator runs the test.

C. Surface Tension Test of Texas Co.

The results obtained on the surface tension test vary considerably among the different laboratories. Several laboratories reported difficulty in obtaining check results. An experienced operator found it necessary to make several runs on each oil to make sure reproducible results were being obtained. This makes the test very time consuming. One member suggests cleaning the tip of the pipette with ether after it is filled with oil and is ready to immerse in the distilled water or caustic solution in order to remove the oil film from the rim of the orifice. Great care must be taken to remove this oil film or low results are obtained due to the distortion of the drops, especially in distilled water. The agreement in results is fairly good if a few low results could be accounted for in this manner. The test is undoubtedly of value for investigation work but the members evidently feel that it is not satisfactory as a referee or plant control test.

This test is evidently applicable to as wide a viscosity range as any of the tests and should give a comparison of the relative emulsifying tendencies of high-viscosity oils.

From a comparison of the average results in Table III, this test would seem to show numerically the relative tendency of good oils to emulsify. However, the results of the individual laboratories do not always classify the oils in the same order, so it is not safe to draw the conclusion that the average results are the correct values for the oils.

From an examination of the above data it is becoming more and more apparent that the differences in emulsification tendencies as now recorded by these tests are due in no small degree to the type of emulsion produced. In view of the fact that highly purified petroleum oils, when mixed with extremely simple emulsifying agents, can often give complicated types of emulsions, it is to be expected that this difficulty would be encountered even more in the case of commercial oils which contain various kinds of emulsifying agents, either present originally in the oil or produced during the process of refining. For example, the A.S.T.M. Steam Emulsion Test and the Herschel Demulsibility Test involve nearly always the production and breaking of a water-in-oil type of emulsion, whereas in the Sinclair Test, and often in the Texas Co. test, an oil-in-water type of emulsion is involved.

EMULSIFYING PROPERTIES OF OILS, USING ALKALINE SOLUTIONS

Although there is a difference of opinion regarding the real value of an emulsion test on an oil using alkaline solutions instead of water, nevertheless in view of certain specifications which now call for such a test, for example, the Navy Test using caustic soda, some preliminary work has been conducted to determine the emulsifying properties of oils when caustic soda solution is added to the oil during the regular test in the Steam Emulsion apparatus. The method of conducting these experiments was as follows:

The size of sample, apparatus, and rate of steaming are the same as for the Steam Emulsion Test. After steaming the sample for one minute, however, the stopper is raised slightly, and 5 cc. of a normal caustic soda solution are added while still steaming. This lowers the steaming temperature somewhat, but it quickly rises again to 190 to 195° F. (88 to 91° C.). The steaming is continued until the total volume is 40 cc. ± 3 cc. The rate of steaming can be regulated so that the total time is 4.0 to 6.5 minutes. The time and temperature of settling and the readings are the same as for the Steam Emulsion Test. The caustic soda solution must be added while steaming and not before starting the test, otherwise no decided emulsification takes place. The results obtained to date seem to parallel the Navy caustic test, so it was decided to offer this test for comment.

The following are comparative results obtained on the nine samples tested:

Sample	Caustic Steam Emulsion Test, Caustic R. E. Number	Steam Emulsion Test, R. E. Number	Surface Tension Test, Average Values of "*K*"
No. 1T	3.5 4.0	1.5 1.5	0.93
No. 2T	3.5 3.5	1.5 1.5	0.93
No. 3T	20+ 20+	16.0 16.0	0.45
No. SA	3.0 4.0	1.0 1.0	0.92
No. SB	4.5 4.5	1.5 2.0	0.92
No. SC	20+ 20+	4.5 5.0	0.41
No. A1	20+ 20+	20+ 20+	0.28
No. A2	20+ 20+	11.5 11.5	0.82
No. A3	9.0 8.5	3.0 3.5	0.89

Comparing the above tabulated data, it will be noted that the caustic R. E. number serves a similar purpose to the value of *K*, obtained by the surface tension method. In other words, oils which have about the same R.E. number, such as, for example, No. SC and No. A3, but which show noticeably different results on the surface tension method, are likewise differentiated with regard to their behavior toward alkaline solutions when using the caustic steam emulsion test. This test is not yet fully developed, but the results are presented for suggestions and criticisms.

ADDITIONAL RESULTS ON THE CAUSTIC STEAM EMULSION TEST. DATA OBTAINED IN TIDEWATER LABORATORY.

Oil	R. E. Number	Caustic R. E Number	Navy Caustic Test at 130° F.		Saybolt Viscosity at 100° F.
			½ Hour	1 Hour	
No. 1.....	2.5	9.5	Did not pass	Passed	100
No. 2.....	0.5	1.0	Passed	Passed	105
No. 3.....	1.0	1.5	Passed	Passed	140
No. 4.....	1.5	20+	Did not pass	Did not pass	135
No. 5.....	1.0	1.5	Passed	Passed	170
No. 6.....	2.0	4.5	Did not pass	Passed	185
No. 7.....	2.5	20+	Did not pass	Did not pass	190
No. 8.....	3.0	9.0	Did not pass	Passed	230
No. 9.....	1.5	2.5	Passed	Passed	230
No. 10....	2.5	11.0	Did not pass	Did not pass	285
No. 11....	2.0	3.0	Passed	Passed	295

The above data show that the caustic R. E. number, when compared with the R. E. number, tends to give parallel results to the Navy caustic test. Oils Nos. 4, 7 and 10, which do not pass the Navy caustic test after settling one hour, show the greatest difference between the caustic R. E. number and the R. E. number.

PROPOSED WORK

At the March, 1924, meeting of Sub-Committee XI and with the approval of Committee D-2 as a whole, the following decisions were made:

1. To keep the A.S.T.M. Steam Emulsion Test as a tentative standard for another year, continuing further study of certain details.
2. To investigate the possibility of distinguishing more sharply between certain various grades of turbine oils by taking readings to the nearest one-tenth of a minute. Consideration will be given of the proposed method of reporting results for turbine oils, including the viscosity factor.
3. Both the surface tension test and the Sinclair test, although at present not adaptable for referee work, have proved of considerable interest from the standpoint of research work and plant control.
4. Further work on the emulsifying properties of oils in alkaline solutions will be investigated, using more dilute alkali than that already tried.

Respectfully submitted on behalf of the sub-committee,

JAMES T-B. BOWLES,
Chairman.

APPENDIX

Sinclair Emulsion Test for Lubricating Oils

(Suggested by E. B. Phillips)

APPARATUS

1. The apparatus consists of a Hamilton-Beach Drink Mixer No. 5 N made by the Hamilton Beach Manufacturing Co., Racine, Wis. It can be purchased from large electrical supply houses. The stirrer used by Mr. Phillips was obtained from Albert Pick Co., 212 W. Randolph St., Chicago, Catalogue Number 3–E–5462. Twelve plain 8-oz. drinking glasses and a water bath which may be held at 180° F. are also required.

MANIPULATION

2. Fifty cubic centimeters of the oil to be tested are poured into a spotlessly clean 8-oz. glass at 70 to 80° F.; 50 cc. of freely boiling distilled water are added and the glass is placed under the spindle of the drink mixer. The mixture is then stirred for 5 minutes at 12,500 to 13,500 r. p. m. The glass is removed and immediately placed in a water bath at 180° F. for one hour. The sample is then removed for examination.

INTERPRETATION OF RESULTS

3. The results shall be reported as follows:

(*a*) *Perfect.*—When the oil and water separates into two layers with no intervening layer of emulsified oil and water. The oil shall be bright and the water clear.

(*b*) *Good.*—When the oil and water separates into two layers with no intervening layer of emulsified oil and water The oil shall be bright and the water milky-

(*c*) *Medium.*—When the oil and water separates into layers with an intervening layer of emulsified oil and water not exceeding $\frac{1}{16}$ in. in thickness. The oil may be cloudy and the water milky.

(*d*) *Poor.*—When the oil and water does not separate so as to come within the three classes described above.

REPORT OF SUB-COMMITTEE XII ON FLASH

Sub-Committee XII on Flash has made a series of experiments for the purpose of determining:

1. The relation between results obtainable with the Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 - 21 T) (using the solid plate below the cup) and the method as revised in 1923, which represents the modification involving the use of a plate with a circular opening $2\frac{3}{16}$ in. in diameter beneath the cup.

2. The reproducibility in different laboratories of flash and fire points determined by Method D 92 - 23 T (using the cut-out plate).

3. The general nature of the relationship between results of the open-cup flash test (Method D 92 - 23 T) and the Pensky-Martens closed cup as described in the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (D 93 - 22), and the suitability of the latter method as applied to high-flash oils.

Samples representing ten grades of oil have been tested in the laboratories of members of the sub-committee. Reports covering part or all of the work requested have been received from nine laboratories. Tables I and II show average results of flash and fire tests by Methods D 92 - 21 T and D 92 - 23 T, which for purposes of convenience are designated respectively as "Open Cup Solid Plate", and "Open Cup Cut-out Plate". The "average" results from each laboratory are multiples of 5° F. which are nearest to the actual numerical averages.

Table III summarizes the results of Tables I and II, showing averages (again the nearest multiple of 5° F.) for flash and fire tests of each oil as determined by each method. It shows conclusively that the change in the plate does not affect the results of the test. In this connection, mention should be made of the fact that practically all of the laboratories coöperating were definitely in favor of the cut-out plate, due to its greater convenience in use.

The reproducibility of results, using the cut-out plate has been studied from Tables II and III. It appears that about 70 per cent of the individual figures for flash point are within ±5°F. of the average figure for the oil under test. About 25 per cent of the individual figures differ by ±10° F. from the averages.

The fire point figures show about 90 per cent within 5° F. of the average and the remainder within ± 10° F. of the average.

TABLE I.—TESTS WITH OPEN CUP, SOLID PLATE. VALUES IN DEGREES FAHRENHEIT.

Laboratory	300 Oil	Pale Oil	Medium Red Oil	Hy. Red Oil	M-C. Bright Stock	Pa. Bright Stock	M-C. St. Ref. Stock	Pa. St. Ref. Stock	Hy. Pa. St. Ref. Stock	Sinclair 218 Oil
Flash Tests										
No. 1	265	355	410	435	500	555	535	585	620	410
No. 2	260	365	415	445	510	555	535	595	635	420
No. 3	275	365	410	440	505	560	530	595	640	420
No. 4	275	370	425	445	520	565	540	595	640	...
No. 5	255	355	415	445	500	560	535	590	625	425
No. 6	265	360	425	460	...	...	...	...	...	420
No. 7	265	355	415	450	515	565	540	600	645	425
No. 8	270	370	415	455	515	565	545	595	645	420
No. 9	270	365	415	455	520	575	550	605	645	...
Fire Tests										
No. 1	295	410	475	515	585	635	620	670	710	475
No. 2	295	415	480	515	590	640	615	670	715	485
No. 3	295	410	480	515	585	640	610	665	720	480
No. 4	295	420	485	520	585	640	610	670	715	...
No. 5	300	415	475	515	580	635	610	670	715	480
No. 6	295	415	480	520	...	...	...	...	...	480
No. 7	295	410	480	515	590	640	620	680	725	485
No. 8	300	420	475	520	590	645	615	675	720	490
No. 9	300	...	...	...	...	...	...	...	...	...

TABLE II.—TESTS WITH OPEN CUP, CUT-OUT PLATE. VALUES IN DEGREES FAHRENHEIT.

Laboratory	300 Oil	Pale Oil	Medium Red Oil	Hy. Red Oil	M-C Bright Stock	Pa Bright Stock	M-C St. Ref Stock	Pa. St Ref. Stock	Hy. Pa. St. Ref Stock	Sinclair 218 Oil
Flash Tests										
No 1	265	360	410	440	505	555	535	585	620	410
No. 2	260	365	415	445	510	560	535	590	640	415
No. 3	275	365	415	440	505	570	535	595	640	415
No. 4	270	365	425	450	520	570	545	595	640	...
No. 5	255	355	415	445	500	560	535	590	625	425
No. 6	265	355	425	455	520	580	550	615	650	420
No. 7	265	355	415	450	515	565	540	600	645	425
No. 8	270	370	420	460	520	570	540	595	645	420
No. 9	275	360	415	455	515	575	550	605	645	...
Fire Tests										
No. 1	295	410	475	515	585	635	615	670	710	480
No. 2	295	420	480	515	590	645	615	670	710	480
No. 3	300	415	480	515	580	650	620	680	730	480
No. 4	295	425	485	520	580	640	615	675	715	...
No. 5	300	415	475	515	580	635	610	670	715	480
No. 6	295	415	480	520	585	645	625	680	720	480
No. 7	295	410	480	515	590	640	620	680	725	485
No. 8	300	420	480	520	595	645	620	675	720	495
No. 9	300	415	480	520	585	...	625	680	...	...

These facts indicate that the reproducibility of the fire point determinations is satisfactory, but that flash point tests are not always as accurate as might be wished for. The allowable experimental error would seem to be ±5° F., and it appears that almost a third of the results obtained showed greater deviations. These excessive deviations seem, however, to be due largely to two general causes, which would not be effective if the directions for the method were rigidly adhered to. A study of the figures, and of the information regarding laboratory facilities, which was provided by each of the sub-committee members, showed that imperfect control of the rate of heating, and stray air currents over the test apparatus, were the most probable causes of error. The chairman was able to demonstrate conclusively in his own laboratory that the elimination of drafts improved the accuracy of the test very considerably.

TABLE III.—SUMMARY OF RESULTS SHOWING COMPARISON OF FLASH AND FIRE TESTS BY THE OPEN CUP, SOLID PLATE AND OPEN CUP CUT-OUT PLATE METHODS.

	Average Flash Tests[1]		Average Fire Tests[1]	
	Solid Plate	Cut-out Plate	Solid Plate	Cut-out Plate
300 Oil	265	265	295	295
Pale Oil	360	360	415	415
Medium Red Oil	415	415	480	480
Hy. Red Oil	450	450	515	515
M-C. Bright Stock	510	510	585	585
Pa. Bright Stock	565	565	640	640
M-C. St. Ref. Stock	540	540	615	620
Pa. St. Ref. Stock	595	595	670	675
Hy. Pa. St. Ref. Stock	635	640	715	720
Sinclair 218 Oil	420	420	480	485

The open flash method has been in use for several years and has been modified in only one detail of importance since it was originally proposed. This change, the use of a cut-out plate instead of a solid plate, has been shown to have no effect on results. There is a possibility that some change in procedure and interpretation could be worked out which would improve the accuracy of the test when applied under the adverse conditions which exist in some laboratories. Such a change, however, would be likely to cause more confusion than the possible improvement would be worth, and the sub-committee does not feel that it should be considered.

It is therefore recommended that the Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T)[2] be advanced to standard. One change is necessary in the text, which was overlooked when the cut-out plate was adopted. The change is as follows:

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[1] Averages are reported as multiples of 5° F. which are closest to the actual numerical average.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 690 (1923).

Section 2.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> "The cup shall be [heated by contact with] *supported by* a metal plate $\frac{1}{4}$ in. (0.635 cm.) in thickness and 6 in. (15.24 cm.) in width."

Table IV shows the results of Pensky flash tests on the oils tested. Bracketed results are ones that were obviously too far out of line to be counted in the averages. The averages were computed to the nearest even degrees Fahrenheit, and are shown in comparison with open cup tests computed to the nearest even degrees instead of to the nearest multiple of 5° F.

TABLE IV.—PENSKY FLASH POINTS IN COMPARISON WITH OPEN-CUP FLASH POINTS.

Laboratory	300 Oil	Pale Oil	Medium Red Oil	Hy. Red Oil	M-C. Bright Stock	Pa. Bright Stock	M-C. St. Ref. Stock	Pa. St. Ref. Stock	Hy. Pa. St. Ref. Stock	Sinclair 218 Oil
No. 1	255	335	410	435	480	500	525	575	583	410
No. 2	257	(356)	410	441	...	...	...	...	...	411
No. 3	260	343	410	440	475	503	530	573	573	418
No. 5	257	340	408	437	480	510	528	572	(602)	426
No. 7	260	340	405	440	475	495	525	555	570	415
No. 8	252	333	396	428	468	498	520	563	579	413
Average	257	338	407	437	476	501	526	568	576	419
Average results, open cup cut-out plate	267	361	417	449	512	567	541	596	639	419
Difference	10	23	10	12	36	66	15	28	63	0

The relationship here indicated is not quite as regular as was expected, but the figures show that Pensky tests are appreciably lower than open cup tests for products of low flash and high flash; but that the differences are relatively small for a considerable range of "overhead" lubricating oils.

The agreement among Pensky tests is not particularly good for the two or three oils of high flash point and several of the laboratories reported that the apparatus and method were not suitable for products of this class. The Society has never recommended the Pensky method for lubricating oils and the present findings are important evidence in support of the original decision that its use be limited to the testing of fuel oil.

Respectfully submitted on behalf of the sub-committee,

ERNEST W. DEAN,
Chairman.

REPORT OF SUB-COMMITTEE XIII ON ORGANIC ACIDITY AND SAPONIFICATION

Continuing the work described in last year's report, the members of the sub-committee have made tests on two samples of oil by two methods, and additional tests by private methods. Titrating solutions and reagents were sent out with the oils by the chairman in an attempt to secure concordant results.

The first method was a modified form of the method for free acid appearing in the Standard Methods of Testing Lubricants (D 47 - 21)[1] and is as follows:

PROPOSED METHOD FOR DETERMINING ACID NUMBER OF MINERAL OILS

Accurately weigh 20 g. of the oil into a flask. Add 50 cc. of distilled water and 50 cc. of 95-per-cent alcohol which has been neutralized with weak sodium hydroxide. The reagents should be added in the order named to avoid emulsions. Heat to boiling and agitate the flask to dissolve the acids as completely as possible. Titrate while hot with aqueous 0.1 *N* alkali using phenolphthalein as an indicator. The mixture should be kept hot during the titration even if it should require more than one heating, and the flask should be agitated after each addition of alkali.

The normality of the titrating solution shall be determined by checking against an acid of known strength. This acid shall have been standardized by titrating against a weighed amount of pure anhydrous sodium carbonate according to instructions which may be found in any good book on quantitative analysis.[2]

Express results as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 g. of oil).

Duplicate determinations should vary by not more than 5 per cent.

Compounded oils shall be regarded as fatty oils and shall be tested in accordance with the method for free acid of the Standard Methods of Testing Lubricants (D 47 - 21).[1]

The second method was the same except that 100 cc. of 95-per-cent alcohol was used instead of 50 cc. each of water and alcohol and that a 0.1 *N* alcoholic solution of KOH was used instead of a 0.1 *N* aqueous solution. The results of these tests are given in Table I.

With both of these methods a blank was run using exactly the same reagents and procedure as for a sample of oil, except that no oil was added to the flask. The volume of alkali solution required to neutralize the blank was subtracted from the volume required for each sample of oil before making calculations. It was found however that the acidity determined for the oil was too greatly influenced by the error in running the blank, and the method of neutralizing the alcohol is now proposed instead of running a blank.

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[1] 1921 Book of A.S.T.M. Standards.

[2] For example, Lunge and Keane, "Technical Methods of Chemical Analysis," Vol. 1, Part I, p. 84 (1908).

It is recommended that the method for determination of free acid be withdrawn as a standard, and be published as a tentative standard, omitting all references to alkali blue and turmeric and that the modified method be published as information.

TABLE I.—RESULTS OF COMPARATIVE TESTS ON ACIDITY.

	Laboratory							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
METHOD NO. 1, WITH WATER								
Normality	0.1112	0.1024	0.1143	[a]	0.1120	0.1075	0.1116	0.1082
Cubic centimeters for blank	0.08	0.05	0.04	[a]	0.10	0.11	0.10	0.13
Cubic centimeters for Sample No. 1	2.87	2.75	2.84	[a]	2.80	2.81	2.65	2.80
Cubic centimeters for Sample No. 2	0.595	0.350	0.580	[a]	0.550	0.460	0.61	0.504
Acid Number, Sample No. 1	0.894	0.790	0.910	0.835	0.872	0.846	0.830	0.850
Acid Number, Sample No. 2	0.185	0.101	0.186	0.100	0.170	0.136	0.190	0.153
METHOD NO. 2, WITHOUT WATER								
Normality	0.1044	0.0944	0.1051	0.10196	0.1032	0.0962	0.1019	0.0982
Cubic centimeters for blank	0.18	0.16	0.12	0.30	0.20	0.24	0.21	0.30
Cubic centimeters for Sample No. 1	3.19	2.84	3.31	3.10	3.20	3.31	3.16	3.23
Cubic centimeters for Sample No. 2	0.99	0.79	1.20	0.40	0.65	0.60	1.07	0.70
Acid Number, Sample No. 1	0.934	0.752	0.976	0.887	0.918	0.890[b]	0.900	0.890
Acid Number, Sample No. 2	0.290	0.209	0.353	0.114	0.187	0.163[b]	0.300	0.193
PRIVATE METHOD								
Acid Number, Sample No. 1	....	0.878	0.940	0.813	0.826	0.890[b]	0.825	....
Acid Number, Sample No. 2	....	0.177	0.250	0.109	0.230	0.163[b]	0.200	....

[a] Lost, used own solution.

[b] These values obtained by same method.

The attached description of the concentration cell method proposed by D. C. Cox, and results obtained with this method by Max Hecht, are also appended for information. It is planned during the coming year to investigate the concentration cell method, and the possibility of obtaining more accurate results in the neutralization method by the use of weaker alkali solutions.

Respectfully submitted on behalf of the sub-committee,

WINSLOW H. HERSCHEL,
Chairman.

APPENDIX

REPORT OF MAX HECHT TO THE DUQUESNE LIGHT CO., PITTSBURGH, ON CONCENTRATION CELL METHOD OF D. C. COX FOR ORGANIC ACIDITY

To adapt electrometric titration of acidity in oils in place of color indicators.

Conclusions:

1. The electrometric method compared to other methods on serviced turbine oils, gives a greater total acidity than other methods.
2. The titration is conducted in a homogeneous solution the color of which is not a factor.
3. The end point is sharp, and the results are reproducible.
4. The method requires either a potentiometer, galvanometer or millivoltmeter and the use of platinum-blacked platinum electrodes.
5. The time of titration is but slightly longer than the other methods compared.
6. The use of sodium ethylate as the alkali and the phenolphthalein indicator, using the benzol alcohol as a solvent, is found to be more desirable than the National Electric Light Association method, although the end point is less sharp.
7. Alkali blue and the benzol alcohol solvent gives a vague end point.
8. Sodium ethylate is found to be unstable and requires restandardization.

Instruments and Apparatus used:

Potentiometer, portable type, Leeds & Northrup Catalogue No. 75, Figure 7655. Enclosed lamp and scale galvanometer, Leeds & Northrup Catalogue No. 75, Figure 2420-C. Platinized spiral electrodes. Agar-Agar conducting bridge containing potassium iodide. Sodium ethylate 0.05 *N* solution.

Concentration Cell Method (from a paper by D. C. Cox, submitted to Committee D-9 on Electrical Insulating Materials).

Two 150-cc. beakers are placed side by side under two burettes. Ten cubic centimeters of the sample are run into a 100-cc. volumetric flask and made up to the mark with a benzol ethyl alcohol mixture (equal volumes). This is poured into one of the beakers. Ten cubic centimeters of a neutral oil are made up to 100 cc. in the same way and poured into the other beaker. Five cubic centimeters of a saturated solution of potassium iodide are added to each beaker in order to secure conductivity. The beakers are connected electrically by means of a U-tube filled with a conducting jelly. Into each beaker is placed a spiral of clean platinum wire and these wires are connected to some form of potentiometer. A great sensitivity is not required here, for the potential differences are quite considerable.

This jelly is prepared by adding 5 cc. of alcoholic solution of potassium iodide to 100 cc. of water, adding to this 2 g. of agar-agar and heating to 80 or 90° C. (176 or 194° F.).

Six or eight U-tubes made by bending $\frac{1}{2}$-in. glass tubing are filled with this solution which quickly sets to a firm highly-conducting jelly.

A few drops of phenolphthalein are added to the blank and 0.05 *N* sodium ethylate in alcohol is added from the burette until a faint pink color which does not immediately bleach is attained. The potential difference between the electrodes may now be measured. One-half cubic centimeter of sodium ethylate is now added to the beaker containing the sample, the solution is stirred and the potential difference again measured. Thus by steps of 0.5 cc. the titration proceeds. The voltage will be observed to drop quite rapidly. The point where the voltage becomes zero is read as the end point. As the benzol alcohol mixture is not neutral, the titration value of the blank is subtracted from that of the sample. The difference is reported as the number of cubic centimeters of 0.05 *N* alkali required to titrate 10 cc. of sample.

To prepare sodium ethylate solution, metallic sodium is melted under oil and sucked up into glass tubes. The weight of sodium per inch of tubing is determined and a suitable length for making up the solution desired is cut off with a file and dropped directly into ethyl alcohol. When solution has taken place, the liquid is filtered and ready for use.

National Electric Light Association Method:

Twenty grams of oil, to which 50 cc. of neutralized alcohol is added is heated to boiling. Alkali blue is used as an indicator and the mixture is titrated with 0.1 *N* aqueous solution of potassium hydrate until the alcohol layer is discharged of blue or green color.

A.S.T.M. Method (with the quantity of oil but not of reagents increased):

Twenty grams of oil, to which 50 cc. of a solution made up of 25 cc. of distilled water and 25 cc. of neutral alcohol is heated to boiling. Phenolphthalein is used as an indicator, and the mixture is titrated with 0.1 *N* aqueous solution of potassium hydrate until the water layer shows a distinct pink coloration.

"X" Method:

The same solutions were used as in the electrometric method and alkali blue indicator used. The titration was made at room temperature.

"Y" Method:

The same solutions were used as in the electrometric method and phenolphthalein indicator was used. The titration was made at room temperature.

Discussion:

Erratic results were obtained when clean bright platinum electrodes were used. After plating, to obtain a platinum-black deposit, the titrations were reproducible.

On used oils, the N.E.L.A. method requires careful observation for the color change as did the A.S.T.M. method. For new oils, the color change by either the N.E.L.A. or A.S.T.M. method is very sharp and distinct.

In order to eliminate the emulsified condition found when titrating serviced oils by either the N.E.L.A. or A.S.T.M. method, the "X" and "Y" methods were tried, since it was believed that in a homogeneous solution the end point would be sharp.

The alkali blue indicator is worthless in method "X," the end point being very vague and results could not be duplicated.

The phenolphthalein indicator is somewhat better, but due to the reddish appearance of the oil, before completing the titration, the color change is somewhat masked.

The electrometric titration gives higher values than the other methods used.

The "Y" and N.E.L.A. methods agree closely with one another.

The A.S.T.M. method for a 1.5-mg. oil is higher than either the N.E.L.A. and "Y" methods.

The "X" method, although reported, is a very low value.

When the "Y" method is used, an excess of alkali is required to make certain that a definite and permanent red end point is reached.

Method	Indicator	Standard Solution	Solvent	Temperature	Quanity of Oil, g.	Acid Number				
						Sample No. 1, Serviced Oil	Sample No. 2, Serviced Oil	Sample No. 3, Serviced Oil	Sample No. 4, Serviced Oil	New Oil
Cox	Potential	0.05 *N* $NaOC_2H_5$	50 cc. benzol 50 cc. absolute alcohol 5 cc. sat. K. I.	Room	10	....	1.79	....	....	....
						....	1.62	....	....	....
						3.98	1.72	0.54	0.05	....
						3.94	1.60	0.54	0.08	....
						Av. 3.96	1.68	0.54	0.07	
N.E.L.A.	Alkaline Blue	0.1 *N* KOH	50 cc. neutral alcohol	Boiling	20	....	1.40	....	....	....
						....	1.45	....	....	....
						3.89	1.42	0.40	0.05	....
						....	....	....	....	....
						Av. 3.89	1.42	0.40	0.05	....
A.S.T.M.	Phenolphthalein	0.1 *N* KOH	25 cc. water 25 cc. neutral alcohol	Boiling	20	....	1.51	....	....	....
						....	1.57	....	....	....
						....	....	....	....	....
						....	....	....	....	....
							Av. 1.54			
"X"	Alkaline Blue	0.05 *N* $NaOC_2H_5$	50 cc. benzol 50 cc. absolute alcohol 5cc. sat. K. I.	Room	10	....	1.22	....	....	....
						....	....	....	....	....
						....	....	....	....	....
						....	....	....	....	....
							Av. 1.22			
"Y"	Phenolphthalein	0.05 *N* $NaOC_2H_5$	50 cc. benzol 50 cc. absolute alcohol 5 cc. sat. K. I.	Room	10	....	....	....	....	....
						....	1.58	....	....	....
						4.03	1.41	0.43	0.04	0.03
						....	1.43	....	....	....
						Av. 4.03	1.47	0.43	0.04	

In all of the above work, except the N.E.L.A. and A.S.T.M. methods, it was found that mechanical stirring was of a distinct benefit.

Instead of using the volume of 10 cc. of oil, the weight of oil used in the electrometric test for both new and serviced oils was 10 g., to which was added in each case 100 cc. of the solvent.

REPORT OF SUB-COMMITTEE XIV ON WATER AND SEDIMENT

The sub-committee presents the following revisions of existing tentative standards:

1. *Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 23 T)*[1].—

Section 9.—Add the following sentence at the end of the second paragraph of this section:

> "A loose cotton plug shall be inserted in the top of the condenser tube to prevent condensation of atmospheric moisture in the condenser tube."

It is recommended that with this revision the method be submitted to letter ballot of the Society for adoption as standard.

2. *Tentative Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge (D 96 - 21 T)*[2].—

Section 6 (a).—Change the temperature of the bath specified in this section from 100° F. to 120° F.

Figure 1.—Change Figure 1 to conform to the accompanying Fig. 1, eliminating the dimensions and correcting the proportions.

It is recommended that the tentative method revised as indicated be submitted to letter ballot of the Society for adoption as standard.

Respectfully submitted on behalf of the sub-committee,

H. R. **Gundlach,**
Chairman.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 23, Part I, p. 694 (1923).

[2] *Proceedings,* Am. Soc. Testing Mats., Vol. 21, p. 670 (1921).

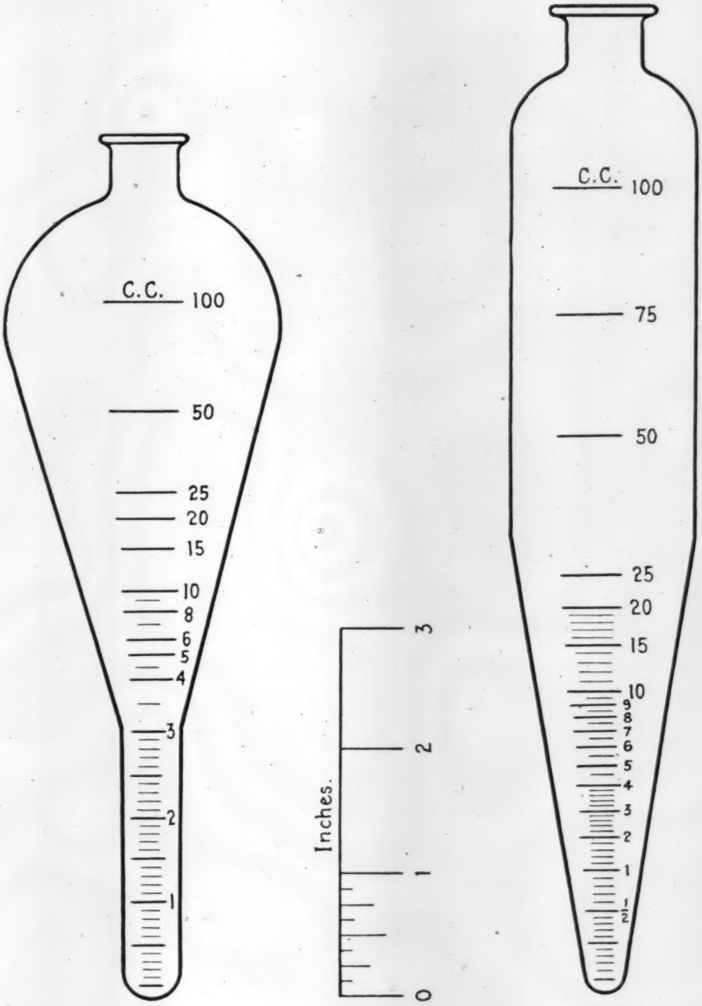
C.C.
Inches.
C.C.
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FIG. 1

REPORT OF SUB-COMMITTEE XVI ON CLOUD AND POUR TEST

At the annual meeting of the Society last year, it was called to the attention of the sub-committee that the method had not been thoroughly tried out on low pour point oils.

Through the kindness of Mr. F. A. Hull, the members of the sub-committee were sent a sample of low pour point switch oil by Mr. E. A. Snyder of the Pittsfield laboratory of the General Electric Co.

This sample was tested by the various members of the committee in accordance with the tentative method and the following results were obtained:

LABORATORY	COOLING MEDIUM	POUR POINT
No. 3	Carbon dioxide and acetone	−25° F.
No. 10	" " " "	−35° F.
No. 7	" " " "	−30° F.
No. 11	" " " "	−35° F.
No. 4	" " " "	−35° F.
No. 1	Ammonia	−30° F.
Average		−31° F.

The result obtained in the laboratory of the General Electric Co. was −35° C. or −31° F.

The above results indicate that the method as it stands is satisfactory for oils having a low pour point. It will probably be best, however, to modify the method so that the person making the test may use a smaller insulated container for the carbon dioxide and acetone, as the present container requires a much greater quantity than is needed. Several members of the committee put the test jar right in the cooling mixture and could not note any particular difference in the results obtained with this oil.

The matter of preparing specifications for a special thermometer to use with low pour point oils has been referred to Committee D-15 on Thermometers.

It appears that the method is still unsatisfactory for certain kinds of cylinder stocks due to varying results obtained depending upon the temperature to which the oil has been heated. These stocks are often kept in various refineries at different temperatures, and in order to make the method of real value, it will be necessary to develop, if possible, some way of getting check results no matter what the initial temperature of the oil is.

Two samples of cylinder stocks giving erratic results were submitted to members of the committee to obtain comparative results.

The first sample was sent out with a request to heat the oil to 165° F. and 220° F., respectively, and then determine pour points showing them in comparison with the result obtained without any modification of the method.

The returns to date are as follows:

Laboratory	Preheating to 165° F.	Preheating to 220° F.	Method D 97 - 23 T
No. 1	5° F.	10° F.	..
No. 3	5° F.	0° F.	..
No. 6	25° F.	5° F.	55° F.
No. 11	20° F.	25° F.	60° F.
Non-Member	0° F.	0° F.	65° F.

The non-member kindly checking the results on this oil was the Atlantic Refining Co. They have given the chairman much help during the past year on the oils with erratic pour points.

Laboratory No. 1 obtained the above results by observing the oil every 5° F. The value of 30° F. was obtained by not testing the sample until it was cooled to 40° F.

Laboratory No. 6 found that 15 hours after heating to 220° F. the pour point was 25° F.

The second sample was sent out to members with a request to try the old stirring method described under "Cold Test" in the Tentative Tests for Lubricants (D 47 - 17 T)[1] in comparison with the present tentative standard.

The oil was to be heated to 90° F., 165° F. and 220° F., respectively, before trying the stirring method. Another sample was to be chilled solid and then heated to 90° F.

Returns to date are as follows:

	Stirring Method				
Laboratory	Heating to 90° F.	Heating to 165° F.	Heating to 220° F.	Solid, then to 90° F.	Method D 97 - 23 T.
No. 1	70° F.	70° F.	70° F.	70° F.	75° F.
No. 3	65° F.	85° F.	90° F.	85° F.	75° F.
No. 4	95° F.	95° F.	100° F.	95° F.	70° F.
No. 6	75° F.	75° F.	75° F.	75° F.	70° F.
No. 9	90° F.	90° F.	90° F.	90° F.	70° F.
No. 10	75° F.	75° F.	75° F.	75° F.	75° F.
No. 11	60° F.	55° F.	50° F.	75° F.	70° F.

Apparently the human equation involved in the stirring method is not conducive to check results and it is useless to look further in that direction for solving the difficulties encountered with these oils.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, p. 767 (1917).

It is rather interesting that on the second sample such good check results were obtained using the tentative method as it now stands.

In view of the erratic results obtained with some oils, it has been deemed best by the sub-committee to hold the method tentative and see if the difficulty cannot be solved during the coming year.

A new type of test jar was submitted by the General Electric Co. As it seemed to have some good points, the chairman had samples made and sent to the members. After trying the new jar, the consensus of opinion is that the type of jar now specified is satisfactory.

Mr. J. B. Rather, a member of this sub-committee, submitted a report on work done in the laboratory of his company on numerous oils having erratic pour points. This paper is appended to this report. It is planned to carry out comparative tests along the lines suggested during the coming year.

Respectfully submitted on behalf of the sub-committee,

RALPH R. MATTHEWS,
Chairman.

APPENDIX

A PROPOSED MODIFICATION OF THE A.S.T.M. POUR TEST APPLICABLE TO THOSE OILS WHICH GIVE ERRATIC RESULTS BY THE PRESENT METHOD

By J. B. Rather and H. M. Anderson

It is a well known fact that the present A.S.T.M. Pour Test method as described in the Tentative Method of Test for Cloud and Pour Points of Petroleum Products (D 97 – 23 T)[1] gives erratic results on certain types of oils, and it has been proposed to secure uniformity by preheating the sample to some arbitrarily selected temperature. This is objectionable because the pour test obtained on a preheated sample very frequently depends upon the degree of preheating, and because some oils under this treatment give results which bear no relation whatever to the condition the oil will ultimately attain when stored at ordinary atmospheric temperatures. The purpose of our work was to secure uniformity in testing, regardless of any previous heat treatment, or storage conditions, of the sample, and at the same time to obtain results which would be related to the actual condition the oil reaches in storage.

Table I.—Influence of Varying Degrees of Preheating on A.S.T.M. Pour.

Laboratory	Description	Pour Point, deg. Fahr.										
		No Heating (70° F.)	Heating to 90° F.	Heating to 105° F.	Heating to 115° F.	Heating to 140° F.	Heating to 165° F.	Heating to 175° F.	Heating to 190° F.	Heating to 220° F.	Heating to 300° F.	Heating to 400° F.
No. 35560	Wyoming No. 35 Oil	30	30	30	35	35	35	35	35	35	30	30
No. 35561	Wyoming No. 45 Oil	25	30	30	35	30	35	30	30	35	35	35
No. 35627	Wyoming No. 307 Oil	65	70	80	75	80	80	75	80	75	75	75
Stock	FFF Valve Oil	45	45	45	45	45	40	40	40	40	40	40
No. 55155	Summer Black Oil	25	50	60	60	45	15	15	15	15	15	15
No. 55154	Pennsylvania A Cylinder Oil	30	45	65	85	55	30	30	25	20	20	25
No. 56766	Mid-Continent Cylinder Oil	...	60	80	85	90	90	35	35	55	50	70
No. 55248	Ranger A Oil	65	70	80	85	90	85	70	85	85	90	85

Eight oils were selected for this work, most of them were oils which gave abnormal results by varying heat treatments previous to testing. In our preliminary experiments we found that in many cases repetition of the A.S.T.M. procedure on the same sample one or more times caused the oil to return to its final equilibrium with regard to pour point, regardless of previous heat treatment, when the equlibrium was taken to be the condition the oil attained in laboratory storage. It was found, however, that heat treatment of certain oils produced a semi-permanent elevation of pour point not rectified by this procedure, and that heat treatment of certain others produced a semi-permanent lowering of the pour point not rectified by the method of test.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 698 (1923).

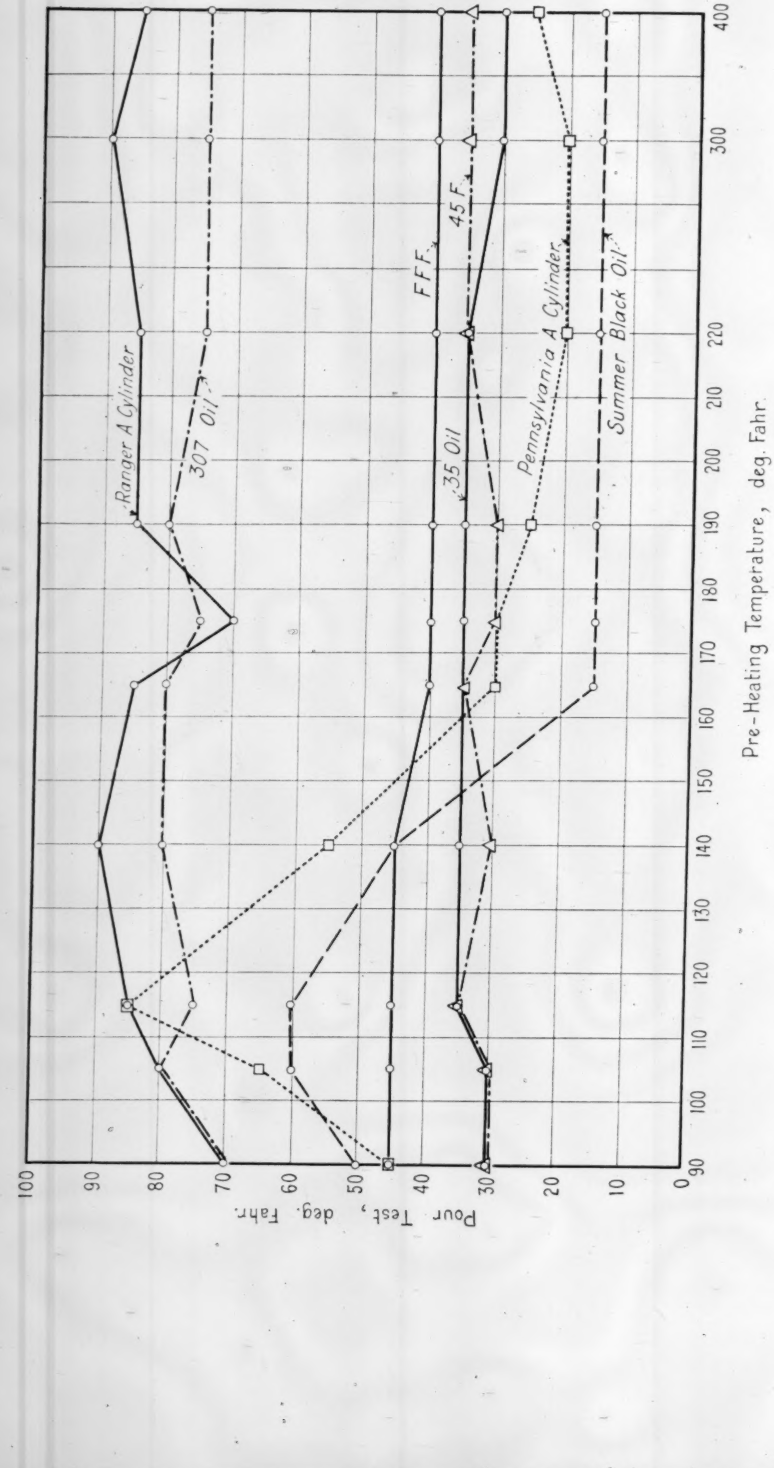

FIG 1.—Effect of Preheating on Pour Test of Oils.

The above experiments led to a study of the influence of pre-heating over a range from 90 to 400° F. on the results secured by the A.S.T.M. Method. This study, results of which are shown in Table I and Fig. 1, indicated clearly that there was a definite "high-point" with every oil, at which preheating temperature the maximum possible pour test would be obtained.

This "high point" was at about 115° F. with all of the oils tested.

On the basis of the above work the following procedure was developed:

Put the oil in the cold test jar, insert thermometer, and cool in the A.S.T.M. cold test apparatus until the oil ceases to flow. Remove and heat, without stirring, to a temperature of 115° F., in a bath maintained at about 118° F. Cool to 90° F. in air and make the pour test in the usual manner. Verify the result by reheating to 115° F. and testing as before. The two tests should agree within the limit of error (5° F.).

In only one case was it necessary for us to repeat the test more than once to secure the maximum possible pour test in those cases where the samples had previously been subjected to varying degrees of heat within the same day. In no case was it necessary to repeat the test at all when the samples had been subjected to high temperatures 24 hours previous to testing.

TABLE II.—POUR TEST BY PROPOSED METHOD ON SAMPLES WITH VARYING DEGREES OF PREHEATING.

Laboratory	Description	Pour Point, deg. Fahr.									
		70° F.	90° F.	165° F.	220° F.	115° F.	220, 24, 115° F.[a]	165, 115° F.	220, 115° F.	300, 115° F.	400, 115° F.
No. 35560..	Wyoming No. 25 Oil........	30	30	35	35	35	35	35	35	35	35
No. 35561..	Wyoming No. 45 Oil........	25	30	35	35	35	35	35	35	35	35
No. 35627..	Wyoming No. 307 Oil.......	65	70	80	75	75	80	80	80	80	75
Stock......	FFF Valve Oil.............	45	45	40	40	45	40	40	40	40	40
No. 55155..	Summer Black Oil..........	25	50	15	15	60	65	65	60	65	60 (2)
No. 55154..	Pennsylvania A Cylinder Oil	30	45	30	20	85	85	85[b]	85[b]	80[b]	80[b]
No. 56766..	Mid-Continent Cylinder Oil	..	60	90	55	85	85	90	85	85	85
No. 55248..	Ranger A Oil..............	65	70	85	85	85	90	90	90	90	90

[a] Heated to 220° F., allowed to stand 24 hours at room temperature (80° F.), heated to 115° F., cooled to 90° F., and tested.

[b] Stood over night before testing.

The above method was tried on oils which had been preheated to temperatures ranging up to 400° F., with results as shown in Table II.

As a result of this work we have reached the following conclusions:

1. If an oil is heated to any specified temperature prior to testing, or immediately prior to receipt by the testing laboratory, the pour point will depend on the temperature to which the oil has been heated.
2. In all cases the "high point," that is, the preheating temperature at which the maximum possible pour point is attainable, is at about 115° F., and the pour thus obtained more truly represents the ultimate condition the oil will reach in storage than any other.
3. In order to secure concordant results regardless of any previous heat treatment to which the oil has been subjected prior to receipt by the testing laboratory, it is only necessary to carry out the simple procedure outlined

above. No sample, the heat treatment of which has occurred 24 hours previous to testing, requires repetition of the procedure to yield concordant results.

In view of the above, the following modification of the Tentative Method of Test for Cloud and Pour Points of PetroleumPro ducts (D 97 - 23 T) is recommended to the consideration of the Sub-Committee on Cloud and Pour Test:

1. *Section 11.*—Eliminate the first sentence. Add the following at the end of the second paragraph: "Heat, without stirring, to a temperature of 115° F., in a bath maintained at a temperature of not higher than 118° F.; then cool to 90° F. in air."

TABLE III.—PHYSICAL TESTS ON OILS USED.

Laboratory	Description	Gravity, deg. A.P.I.	Flash Point, deg. Fahr.	Fire Point, deg. Fahr	Viscosity
No. 35560..	Wyoming No. 35 Oil	23.9	435	495	79 sec., 210° F.
No. 35561..	Wyoming No. 45 Oil	23.3	455	515	135 sec., 210° F.
No. 35627..	Wyoming No. 307 Oil	22.7	540	605	170 sec., 210° F.
Stock......	FFF Valve Oil	25.7	510	600	138 sec., 210° F.
No. 55155..	Summer Black Oil	22.3	425	485	535 sec., 130° F.
No. 55154..	Pennsylvania A Cylinder Oil	24.8	540	610	155 sec., 210° F.
No. 56766..	Mid-Continent Cylinder Oil	22.1	505	580	162 sec., 210° F.
No. 55248..	Ranger A Oil	21.3	535	615	175 sec., 210° F.

2. *Section 11.*—At the end of the last paragraph, add the following: "In those cases where it is known that the sample has been subjected to some temperature higher than 115° F. during the preceding 24 hours, or where the history of the sample in this respect is not known, the sample shall be held in the laboratory 24 hours before testing, or the above procedure shall be repeated on that portion of the sample which has been used in the above test, without transfer or stirring, until three consecutive concordant results are obtained."

REPORT OF SUB-COMMITTEE XVII ON GASOLINE

Sub-Committee XVII has concentrated all its efforts on the Copper Strip Corrosion Test for detection of elementary and corrosive sulfur compounds and the Gum Formation Test.

COPPER STRIP TEST

Samples of gasoline were sent to members of the sub-committee with a request that they try the method as suggested by Mr. R. E. Wilson, namely, comparing the copper strips kept for 3 hours at 122° F. in different grades of gasoline with a standard strip kept in a medicinal oil for 3 hours at 122° F. containing exactly 0.00015 per cent sulfur by weight. The medicinal oil for the test should not show any effect on copper strips by previous testing.

As only a few reports have been received, no conclusions can be drawn at present.

The sub-committee has also under consideration a method for preparing standard copper strips, suggested recently by Mr. R. E. Wilson, namely, dipping a polished copper strip for 15 seconds in 100 cc. of a 0.1 N solution of sodium sulfide, diluted to 0.001 N with distilled water. The time did not allow the investigation of this particular procedure.

GUM FORMATION TEST

A method was drawn up for a gum test using copper and glass dishes. Also, provisions have been made to keep air currents and light from samples during evaporation. Samples of gasoline were sent to the members of the sub-committee to try this method and it is expected that results will be available in the near future.

Respectfully submitted on behalf of the sub-committee,

I. K. GILES,
Chairman.

REPORT OF SUB-COMMITTEE XVIII ON GAS OIL

Sub-Committee XVIII recommends that the Tentative Methods of Testing Gas Oils (D 158 – 23 T) be continued as tentative for another year.

Criticism of the methods has been confined to the Distillation Method. These criticisms are:

1. Objection to the Saybolt distilling flask on the ground that it differs only slightly in dimensions from the so-called "250-cc. Engler distilling flask" specified in the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 18) and is therefore at variance with the policy of the Society to bring about simplification of apparatus.

Committee D-2 has referred this matter to its representative on the Sub-Committee on Volatility of Committee E-1 on Methods of Testing with instructions to undertake to reach agreement on the Saybolt distilling flask, since investigation of the specification for the so-called "250-cc. Engler flask" has shown it to be incomplete and open to misinterpretation.

2. Objection to that portion of the distillation procedure specifying procedure in case cracking is evidenced, on the ground that it will complicate the interpretation of gas oil specifications which provide that a stated percentage shall distill below 700° F.

The chairman is sending out samples of gas oil to a number of laboratories for test, with the hope that further test data will crystallize opinion on this matter.

3. Request has been made that a table for barometric correction of distillation data be included as a footnote to the distillation method.

The sub-committee has voted favorably on this request and the preparation of such data has been referred to the Sub-Committee on Distillation.

Respectfully submitted on behalf of the sub-committee,

Charles A. Lunn,
Chairman.

REPORT OF SUB-COMMITTEE XIX ON ILLUMINATING OILS

The sub-committee has been engaged during the year on the following work:

1. *Development of Specifications for Apparatus for Conducting Burning Tests on Household Illuminating Oils.*—The chairman has been able to secure no assistance whatever from the manufacturers of the chimney and burner in this respect, and has been forced to rely wholly on sources within his own laboratory for this purpose. The sub-committee offers the method given in the 1923 Report of Committee D-2, amended as regards specifications for equipment, for publication as a tentative method of test. It is appended hereto.[1]

2. *Study of Methods of Testing Long-Time Burning Oils, for Railway Use.*—The only progress that has been made in this respect has been on a study of the relation between iodine number and burning quality, given later in this report. The sub-committee has attempted to secure agreement on a burner suitable for testing purposes, with no success whatsoever. U. S. Railway Signal Association representatives most concerned with this work have hesitated to indicate a preferred burner. The attitude of one railroad, and this is perhaps a reflection of the attitude of most, is that oil purchased by them will have to be tested in their type of burner. The U. S. Government in Bureau of Mines *Technical Paper No. 323*, (Method 210.3) specifies "the purchaser's standard burner, chimney and wick." Since the number of different types of long-time burners which have appeared on the market from time to time is astounding, and since no two types of burners which have come to the sub-committee's attention give the same results, no real progress can be made in developing a satisfactory method of test until agreement is reached as to the details of the equipment. A method allowing the optional use of vital parts of test equipment would lead nowhere, and would be, as is the case to-day, a constant source of trouble and misunderstanding. The sub-committee desires to stress this point for the purpose of calling attention to the very great difficulties in the way of developing a method satisfactory to the majority of users.

RELATION BETWEEN IODINE NUMBER OF LONG-TIME BURNING OILS AND BURNING QUALITY, WITH ESPECIAL REFERENCE TO SMOKE TENDENCY

In accordance with the instructions given to Sub-Committee XIX to investigate and report on what relationship, if any, exists between the iodine number and burning quality of illuminating oils, the chairman secured samples of long-time burning oils from sub-committee members and made tests as shown below:

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[1] See p. 888.—ED.

1. Iodine Number:
    - (*a*) Hanus Method, Bureau of Mines *Technical Paper No.* 181, p. 6;
    - (*b*) Added Iodine (Johannsen);
    - (*c*) Substituted Iodine (Johannsen), ***Journal***, Industrial and Engineering Chemistry, Vol. 14, 288 (1922);
2. Burning test according to three different methods as follows:
    - (*a*) Method 210.3 (Bureau of Mines *Technical Paper No. 323*, with modifications as shown below).

The railway semaphore lamp was fitted with a specially selected long-time burner which we shall designate as No. 1. This burner was selected because it gave an exaggerated smoke tendency. The chimney used was the same throughout all the tests.

The test was made by setting the flame just under the smoke point, and allowing the lamp to burn until smoke was observed streaming out from the top of the lamp. The flame was measured daily until smoke was observed, or until the flame had dropped to a point where it was obvious that smoking would not take place.

(*b*) The same apparatus was used as above.

The test was made by setting all flames at $\frac{3}{4}$ in. and allowing them to burn until smoke appeared or the flame had dropped to a point where it was obvious that smoking would not take place.

(*c*) Another test was made in the semaphore lamp fitted with another type of long time burner, which we shall designate as No. 2.

The flame was set at $\frac{3}{4}$ in. and allowed to burn for a period of 5 days. Daily observations were made as to smoke tendency and flame height.

The results of the test are shown in Table I.

Discussion of Results:

1. Oils burned in burner No. 1, especially selected for exaggerating smoke tendency and with flame heights just below the smoke point of each oil, gave results as follows:

(*a*) The highest iodine number oil smoked in $1\frac{1}{2}$ hours, but the lowest iodine number oil smoked in 5 hours.

(*b*) The next to lowest iodine number oil did not smoke for duration of test, but the next to highest iodine number oil likewise did not smoke for duration of test.

TABLE I.—COMPARISON OF IODINE NUMBERS WITH ALL BURNING TESTS.

Sample	Added Iodine A	Substituted Iodine S	A+2S	Iodine Number (Hanus)	Initial and Final Flame Height, in	Hours Burned before Smoking	Cubic Centimeters Burned per Hour	Wick Incrustation	Chimney Deposit
BURNER NO. 1.—FLAME SET JUST UNDER SMOKE POINT									
No. 1....	1.3	4.7	10.7	7.7	$1\frac{1}{16}$	5	7.7	Practically none	Clean
No. 2....	1.7	6.0	13.7	9.9	$1\frac{1}{16}$ $\frac{11}{16}$	70.5[a]	5.9	Slight hard, cokey	White and brown
No. 3....	1.5	6.9	15.3	11.0	$\frac{7}{8}$	4.5	5.5	Practically none	Brown
No. 4....	2.0	8.4	18.8	14.2	$\frac{29}{32}$	13.0	7.5	Slight hard, granular	White
No. 5....	4.0	8.5	21.0	15.2	$\frac{7}{8}$	4.0	3.8	Practically none	Clean[b]
No. 6....	9.9	4.4	18.7	17.2	1	$3\frac{3}{4}$	8.0	Practically none	Clean
No. 7....	6.5	8.9	24.3	18.9	$1\frac{11}{16}$ $1\frac{3}{16}$	48[a]	8.6	Slight hard, lumpy	White[b]
No. 8....	5.9	11.9	29.7	23.7	$\frac{7}{8}$	7.0	7.0	Practically none	White and smoky
No. 9....	5.6	11.9	29.4	24.0	$\frac{7}{8}$ $\frac{9}{16}$	48[a]	4.3	Slight hard, cokey	Brown
No. 10...	13.4	12.0	37.4	33.2	$\frac{15}{16}$	1.5	6.3	Practically none	White
Benzol...	0.0	0.0	0.0	0.0	$\frac{3}{8}$	20 min.	....	....	....
Xylol....	1.0	4.9	10.8	6.0	$\frac{3}{8}$	45 min.	....	....	....
BURNER NO. 1.—FLAME SET AT $\frac{3}{4}$ IN.									
No. 1....	1.3	4.7	10.7	7.7	$\frac{3}{4}$ $\frac{7}{8}$	120[a]	6.1	Slight hard, granular	Gray
No. 2....	1.7	6.0	13.7	9.9	$\frac{3}{4}$ $\frac{9}{16}$	120[a]	5.4	Hard, lumpy	Brown liquid
No. 3....	1.5	6.9	15.3	11.0	$\frac{3}{4}$	2.5[c]	4.3	Practically none	Brown
No. 4....	2.0	8.4	18.8	14.2	$\frac{3}{4}$	4.0[c]	6.2	Slight hard, granular	White
No. 5....	4.0	8.5	21.0	15.2	$\frac{3}{4}$	15.0[c]	5.7	Practically none	Clean
No. 6....	9.9	4.4	18.7	17.2	$\frac{3}{4}$	4.5[c]	6.9	Practically none	Slight white and brown
No. 7....	6.5	8.9	24.3	18.9	$\frac{3}{4}$	4.0[c]	5.7	Slight granular	White
No. 8....	5.9	11.9	29.7	23.7	$\frac{3}{4}$	2.5[c]	4.6	Practically none	White
No. 9....	5.6	11.9	29.4	24.0	$\frac{3}{4}$ $\frac{9}{16}$	[d]	3.5	Medium cokey	Brown and white
No. 10...	13.4	12.0	37.4	33.2	$\frac{3}{4}$	5.0	6.3	Practically none	Slight white
Benzol...	0.0	0.0	0.0	0.0	Smoked at $\frac{3}{4}$ in.				
Xylol....	1.0	4.9	10.8	6.0	Smoked at $\frac{3}{4}$ in.				
BURNER NO. 2.—FLAME SET AT $\frac{3}{4}$ IN.									
No. 1....	1.3	4.7	10.7	7.7	$\frac{3}{4}$ $\frac{3}{16}$	120	4.8	Medium hard, granular	White
No. 2....	1.7	6.0	13.7	9.9	$\frac{3}{4}$ $\frac{3}{4}$	120	4.4	Medium lumpy	White and brown
No. 3....	1.5	6.9	15.3	11.0	$\frac{3}{4}$ $\frac{7}{8}$	120	4.4	Semi-glossy, heavy, hard, lumpy	Heavy brown
No. 4....	2.0	8.4	18.8	14.2	$\frac{3}{4}$ $\frac{3}{4}$	120	4.4	Heavy, glossy, lumpy	White and brown
No. 5....	4.0	8.5	21.0	15.2	$\frac{3}{4}$ $\frac{5}{8}$	120	3.4	Heavy, semi-glossy, lumpy	White and brown
No. 6....	9.0	4.4	18.7	17.2	$\frac{3}{4}$ $\frac{13}{16}$	120	4.9	Medium hard, granular	Slight white
No. 7....	6.5	8.9	24.3	18.9	$\frac{3}{4}$ $\frac{3}{4}$	120	3.8	Semi-glossy, fairly heavy, hard, lumpy	White and brown
No. 8....	5.5	11.9	29.7	23.7	$\frac{3}{4}$ $\frac{7}{8}$	120	4.6	Slight semi-glossy, hard, lumpy	Slight white
No. 9....	5.6	11.9	29.4	24.0	$\frac{3}{4}$ $\frac{11}{16}$	120	3.4	Heavy glossy, cokey	Slight white
No. 10...	13.4	12.0	37.4	33.2	$\frac{3}{4}$ $\frac{7}{8}$	120	4.8	Medium lumpy	White and brown
Benzol...	0.0	0.0	0.0	0.0	Smoked at $\frac{3}{4}$ in.				
Xylol....	1.0	4.9	10.8	6.0	Smoked at $\frac{3}{4}$ in.				

[a] Did not smoke.

[b] Sooty deposit in top lamp

[c] Test checked.

[d] Flame dropped. Test checked.

(*c*) Of those oils that smoked in the tests, the four with Hanus values of 15.2 or below smoked, on an average, in 6½ hours.

(*d*) Of those oils that smoked in the tests, the three with Hanus values from 15.2 to 33.2 smoked, on an average, in 4 hours.

(*e*) Of the three oils which did not smoke, two had Hanus values ranging from 18.9 to 24.

2. All oils burned 120 hours under standard test conditions in the lamp fitted with long-time burner No. 2 without smoking, in spite of a very wide variation in iodine number. Therefore, the test under standard conditions did not reveal any relation between smoke tendency, or other features of burning quality, and Iodine Number.

3. In burner No. 1 with flame set at ¾ in., six oils out of ten, with Hanus values between 11 and 33 smoked in 5 hours or less. Sample No. 2 with Hanus value of 9.9 burned 120 hours without smoking, while Sample No. 3, with practically the same Hanus value (11.0) smoked in 2½ hours, and sample No. 8, with Hanus value of 23.7, smoked in the same length of time. Sample No. 10, with Hanus value of 33.2 likewise smoked in substantially the same length of time (5 hours).

Attention is also called to the relation of iodine number to smoke tendency of benzol and xylol. These two compounds show zero or relatively low iodine numbers, yet each shows a great tendency to smoke.

Conclusions:

1. The true Iodine Number (added Iodine) as indicated by the Johannsen Method is only 13.6 to 57.5 per cent of the Hanus value, which renders results by the latter method open to suspicion of being meaningless.

2. There is no apparent relation between added iodine (Johannsen) or Hanus values and smoke tendency or other burning characteristics of the oils examined and the results show that the only reliable indication of burning quality is to be obtained by burning the oil in a lamp.

Respectfully submitted on behalf of the sub-committee,

J. B. RATHER,
Chairman.

REPORT OF SUB-COMMITTEE XX ON NOMENCLATURE

The sub-committee prepared last year, certain definitions which were published as information as a part of its report for 1923.[1] The definitions were published in order to elicit criticisms and suggestions which have been received and considered by the sub-committee. The sub-committee, therefore, recommends that the following revised definitions and new definitions be presented to the Society for publication for information and criticism:

Crude Petroleum (Crude Oil, Petroleum, Crude).—A naturally occurring mixture, consisting predominantly of hydrocarbons, or of sulfur, nitrogen or oxygen derivatives of hydrocarbons, which is removed from the earth in liquid state or is capable of being so removed.

NOTE.—Crude petroleum is commonly accompanied by varying quantities of extraneous substances such as water, inorganic matter and gas. The removal of such extraneous substances alone does not change the status of the mixture as crude petroleum. If the removal of such extraneous substances also results in the removal of more than a trace of the naturally occurring mixture, the resulting product is no longer crude petroleum.

Topped Crude.—A residual product obtained from crude petroleum by the removal, by distillation, or other artificial means, of an appreciable quantity of the volatile constituents of crude petroleum.

Weathered Crude.—The product resulting from crude petroleum through loss, due to natural causes, during storage and handling, of an appreciable quantity of the more volatile constituents.

Benzine.—This term is archaic and misleading and should not be used.

Petroleum Naphtha.—A generic term applied to refined or unrefined petroleum products and liquid products of natural gas, not less than 10 per cent of which distills below 347° F. (175° C.), and not less than 95 per cent of which distills below 464° F. (240° C.), when subjected to distillation in accordance with the current method of test of the American Society for Testing Materials for petroleum products of this nature.

NOTE.—The "naphthas" used for specific purposes such as cleaning, manufacture of rubber, manufacture of paints and varnishes, etc., are made to meet specifications which may require products of considerably greater volatility than that set by the maximum limits of this generic definition.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 390 (1923).

Gasoline.—A refined petroleum naphtha which by its composition is suited as a carburant for internal combustion engines.

Petroleum Spirits.—A refined petroleum distillate, with a minimum flash point of 70° F. (Tag Closed Tester, A.S.T.M. Standard) with a volatility and other properties making it suitable as a thinner and solvent in paints, varnishes and similar products.

NOTE.—The use of the term "turpentine substitute" is to be condemned as false and misleading. The term "mineral spirits" also should not be used as it includes within its scope not only petroleum products, but other hydrocarbon mixtures, such as coal-tar distillates.

Kerosene.—A refined petroleum distillate having a flash point not below 80° F., as determined by the Tag Closed Tester, A S.T.M. method, and suitable as an illuminant when burned in a wick lamp.

NOTE.—Local ordinances at times require flash points higher than 80° F., Tag Closed Tester, A.S.T.M. Standard.

Mineral Seal Oil.—A refined petroleum distillate, having an open-cup flash point (A.S.T.M. method) not below 250° F., and suitable for use as an illuminant in certain types of wick lamps.

Gas Oil.—A liquid petroleum distillate having a viscosity intermediate between that of kerosene and lubricating oil.

NOTE.—It should be understood that oils, other than gas oil as defined above, may be and are used in the manufacture of gas.

Fuel Oil.—Any liquid or liquefiable petroleum product used for the generation of heat in a furnace or firebox, the controlling factors being cost and adaptability. Fuel Oils in common use fall into one of four classes: (*a*) Residual Fuel Oils, which are topped crudes or viscous residuums obtained in refining processes; (*b*) Distillate Fuel Oils, which are distillates derived directly or indirectly from crude petroleum; (*c*) Crude Petroleums and Weathered Crudes of relatively low commercial value; (*d*) Blended Fuels, which are mixtures of any or all of the three other classes.

Tar, Pitch.—These terms shall not be applied to petroleum products.

Grease.—A combination of a petroleum product and a soap or a mixture of soaps, suitable for certain types of lubrication.

Oil-Shale.—Oil-shale is a compact, laminated rock of sedimentary origin, yielding over 33 per cent of ash and containing organic matter that yields oil when destructively distilled but not appreciably when extracted with the ordinary solvents for petroleum.

Shale Oil.—The crude oil obtained as a distillate by the destructive distillation of oil-shale.

End Point.—End point is the highest temperature observed on the distillation thermometer in conducting the A.S.T.M. distillation test for gasoline, etc.

Respectfully submitted on behalf of the sub-committee,

K. G. MACKENZIE,
Chairman.

REPORT OF SUB-COMMITTEE XXI ON CRUDE PETROLEUM

Following the meeting of Sub-Committee XXI at St. Louis in December, 1923, Messrs. Crosby, Campbell and Terry furnished each member with samples of Tonkawa, Light California and Heavy California crude petroleum, making distillations of these samples to determine the gasoline content in accordance with a general scheme outlined at the meeting.

The reports received to date have been examined and the results are given in the accompanying Table I. A preliminary study of the results indicates that the variation in barometer pressure is not a large factor in influencing the results. Considering the work as a whole, two laboratories, Nos. IV and VII, obtained somewhat lower percentages of gasoline than other laboratories. Three laboratories, Nos. I, III, and VI, agree quite closely among themselves. Of the three methods of distillation, Method C appears to be distinctly less satisfactory than A or B, while, from the standpoint of accuracy, there would seem to be little to choose between methods A and B. The study of the tabulated data is being continued to determine the effect of the various still and tower capacities employed by the different laboratories, and also the effect of the variation in the quantity of crude petroleum charged to the still.

Respectfully submitted on behalf of the sub-committee,

N. A. C. Smith,
Chairman.

TABLE I.—PRELIMINARY SUMMARY IN STUDY OF GASOLINE YIELD FROM THREE CRUDE OILS BY THREE DIFFERENT METHODS.

Laboratory	Percentage Yield of Gasoline by Three Methods									Still			Experimental Details		
	Tenkawa Crude			Light California Crude			Heavy California Crude			Capacity	Dimensions	Stillhead	Approximate Charge of Crude Oil	Barometer Limits, mm.	Remarks
	Method A	Method B	Method C	Method A	Method B	Method C	Method A	Method B	Method C						
I	50.5–50.2	49.0–49.2	48.3–48.3	43.7–43.7	42.4–42.3	43.5–43.8	23.0–23.3	12.0–14.5	17.6–17.8	4000 cc.	Height 8⅛ in.; inside diameter 6 in.	Inside diameter 1½ in.; height to vapor tube 10 in.; height of packing 9 in.	2000 cc. throughout	741–755	Same still throughout.
II	50.7–50.0	48.5–49.6	50.6–50.9	43.0–44.0	42.7–43.5	42.8–44.0	23.9–23.9	17.8–17.2	19.2–18.6	3000 cc.	Spherical copper 7½ in. diam.	Height 9½ in.; inside diameter 1½ in.; height of packing 6 in.	1000 cc. throughout	760–768	Same still used throughout for Methods A, B, and C.
III	50.2–50.3	49.6–49.8	48.9–49.0	42.9–43.0	41.7–41.7	42.9–43.0	23.5–23.5	14.5–15.0	17.8–18.0	3600 cc.	Cylindrical rounded bottom; inside diameter 6¼ in.; height 8 in.	Inside diameter 2 in.; height to vapor outlet 13 in.; height of packing 9½ in.	2000 cc. throughout	746–756	Same still used throughout.
IV	48.5–47.9 48.6	47.8–47.6	46.9–48.1	42.2–42.3	41.8–41.5	42.3–42.2	23.7–23.2	16.8–17.3	17.2–18.1	3250 cc.	Steel still $6\frac{1}{16}$ in. diameter; height 8 in.[a]	Steel, inside diameter 2 in.; height 14 in.; height of jack chain 11 in. Glass, inside diameter 1¼ in.; height 10 in.; height of packing 6 in.	Method B run on 3000 cc.; others on 1000 cc.	759–761	Steel still and Pyrex flask used for Methods A and C. Steel still and B. of M. Hempel used for method B.
V	48.0–48.3	45.6–47.3	44.1–44.3	40.2–40.9	40.6–40.1	40.0–40.7	20.3–20.3	11.3–15.7	13.8–14.0	5000 cc.	6 in. standard wrought iron pipe 12 in. long	Diameter 1½ in.; 10½ in. to vapor outlet; height of packing 9½ in.	15,000 cc. except Heavy California Crude which was run on 3000 cc.	749–764	Same still used throughout.
VI	49.2–49.3	48.9–49.3	47.8–48.1	43.6–43.8	43.3–43.9	43.3–43.6	23.6–23.9	16.1–16.2	16.4–17.0	Described at meeting of Committee D-2, St. Louis, December, 1923.			Method B run on 3000 cc.; others on 1000 cc.	757–770	Method A run in 2-liter still. Method B run in 1-gallon still. Method C run in 2-liter still.
VII	49.3–49.5	49.3–49.6	49.5–49.5	41.9–41.9	40.7–41.6	42.0–41.2 41.9	Sample not received			8350 cc.[b]	Inside diameter 8.06 in.; height 10 in.	Inside diameter 1½ in.; 12 in. to vapor outlet; height of jack chain 11 in.	Method B run on 300 cc.; others on 1000 cc.	762–770	Method A run in 1-gallon still. Method B run in 500-cc. flask. Method C run in 1-gallon still.

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[a] Also used Pyrex round-bottom distillation flask, outlet tube 2½ in. from top, total height 16¼ in.

[b] Describes this still but apparently uses a 1-gallon still and 500-cc. flask in actual work.

NOTE.—This table does not include special runs made by various laboratories.

REPORT OF SUB-COMMITTEE XXII ON NATURAL GAS GASOLINE

As far as the testing of natural gas for gasoline content, this committee is doing no original work but is cooperating with the committee of the Natural Gas Association. On the tests of natural gas gasoline, the chairman included in his tentative report certain proposed modifications to make the distillation test applicable to natural gasoline. These modifications largely involve temperatures of sample, condenser bath, and receiving graduate bath.

These recommendations are to be checked by tests made in the laboratories of the various members of the sub-committee and from them it is expected to formulate definite recommendations for the distillation test.

Respectfully submitted on behalf of the sub-committee,

L. F. Bayer,
Chairman.

REPORT OF SUB-COMMITTEE XXIII ON CARBON RESIDUE

This sub-committee was organized at the time of the meeting of Committee D-2 in Washington in November, 1923. Considerable work on the carbon residue test has been done by the U. S. Bureau of Mines, and the committee has utilized the results of this work in laying out its program. Inasmuch as the Bureau's work was done by one or two men working in the same laboratory, the committee is undertaking to determine whether the results obtained by the Bureau will be confirmed when the determinations are made by a larger number of individuals working in separate laboratories. Two samples were forwarded to each member of the committee, with the request that the carbon residue test described in the Standard Methods of Testing Lubricants (D 47 – 21) be run on 1-g., 2-g., 5-g. and 10-g. samples. Results have been received from all members of the committee, and are as follows:

Laboratory.	Sample No. 1				Sample No. 2			
	1-g.	2-g.	5-g.	10-g.	1-g.	2-g.	5-g.	10-g.
No. 1	10.5	10.0	10.7	7.6	3.5	3.5	3.5	3.7
	10.0	10.3	10.2	...	4.1	3.6	3.5	3.7
Average	10.2	10.2	10.4	7.6	3.8	3.5	3.5	3.7
No. 2	10.01	10.00	11.38	11.40	3.70	3.90	4.18	4.51
	10.59	10.66	11.48	12.28	3.65	3.92	4.22	4.46
	10.25	10.67	11.86	11.84	3.65	3.83	4.15	4.37
Average	10.28	10.44	11.57	11.84	3.67	3.88	4.18	4.45
No. 3	10.27	10.55	10.95	10.58	4.22	4.08	4.09	4.22
	10.40	10.79	10.74	10.82	4.10	4.07	4.11	4.12
	10.55	10.62	10.50	10.69	4.16	4.12	4.14	4.18
Average	10.41	10.65	10.73	10.70	4.16	4.09	4.11	4.17
No. 4	11.06	11.42	11.58	12.05	3.99	3.94	4.25	4.69
	11.13	11.46	11.67	11.97	3.99	3.95	4.24	4.20
	11.09	11.44	11.67	.....	3.96	3.95	4.24	4.07
	.....	.....	10.56	.....	3.57	3.73	4.05	4.24
	.....	.....	.....	.....	3.65	3.63	3.73	....
Average	11.09	11.44	11.37	12.01	3.83	3.84	4.10	4.30

LABORATORY		SAMPLE NO. 1				SAMPLE NO. 2			
		1-G.	2-G.	5-G.	10-G.	1-G.	2-G.	5-G.	10-G
No. 5...	Operator A	11.37	11.38	11.33	12.00	3.89	4.05	4.40	4.40
		11.35	11.27	11.59	12.01	3.98	4.24	4.31	4.34
		11.49	11.09	11.58	12.19	4.02	4.07	4.45	4.4
	Operator B	.....	.....	.....	10.88	....	....	....	....
		.....	.....	.....	10.24	....	....	....	...
	Operator C	.....	.....	.....	10.26	....	....	....	4.43
		.....	.....	.....	10.07	....	....	....	4.34
	Average.....	11.40	11.25	11.50	11.09	3.96	4.09	4.39	4.38
No. 6.........		10.9	10.7	[a]	[a]	3.6	3.9	4.2	4.3
		10.7	11.0	[a]	[a]	3.6	4.1	4.0	4.4
		10.8	10.6	[a]	[a]	3.7	3.8	4.1	4.1
	Average.....	10.8	10.8			3.6	3.9	4.1	4.3

[a] Results very unsatisfactory when method of heating given in D 47 – 21 is closely followed.

The samples tested represent extreme cases, and the committee will continue its work on other oils showing a much lower carbon residue. It is felt that the method of heating is probably the most important factor in the successful conduct of the test, and this will be studied carefully in future work.

It is recommended that the method for carbon residue appearing in the Standard Methods of Testing Lubricants (D 47 – 21)[1] be withdrawn and published as tentative.

Respectfully submitted on behalf of the sub-committee,

F. W. LANE,
Chairman.

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[1] 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS

Committee D-4 has held three meetings during the past year. A number of new specifications have been prepared and revision of a number of existing tentative and standard specifications has been found necessary to harmonize the old with the new. Certain revisions of existing tentative and standard methods of test have also been deemed advisable to meet objections which have been raised and to facilitate their use by other standing committees.

Committee D-4 has given careful consideration to the definitions for specific gravity contained in the annual report of Committee E-8 on Nomenclature and Definitions for 1923[1] and has submitted to Committee E-8 certain recommendations which are appended hereto. These recommendations were referred to letter ballot of Committee D-4 and the following returns received:

Item	Affirmative	Negative	Not Voting
1. Recommendation that term "specific gravity" be used in preference to the term "density" for ordinary technical work	43	0	14
2. Definition for Absolute Specific Gravity	41	1	15
3. Definition for Specific Gravity	42	1	14
4. Definition for Apparent Specific Gravity	42	1	14
5. Definition for Relative Specific Gravity	40	2	15
6. Definition for Relative Apparent Specific Gravity	39	2	16

A Sectional Committee on Asphalt Content, of the Sub-Committee on Bituminous Materials, has prepared a report containing a recommended method for use in cooperative tests which are now being conducted. While Committee D-4 is not now prepared to recommend this method to the Society it believes that a description of the method will be of considerable value to those interested in testing bituminous materials and therefore appends hereto the report of its Sectional Committee on Asphalt Contents.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 523 (1923).

PROPOSED REVISIONS OF EXISTING STANDARD METHODS AND SPECIFICATIONS

No. 1. *Standard Method of Test for Softening Point of Bituminous Materials* (*Ring-and-Ball Method*) (*D 36 - 21*).[1]—During the past year this method was submitted to the American Engineering Standards Committee for adoption as a Tentative American Engineering Standard but was later withdrawn, owing to certain criticisms which were received. The following revisions are now recommended in this method:

Section 2 (*d*).—Substitute for the present requirements for thermometers, the specifications for low-softening-point thermometer recommended by Committee D-15 on Thermometers and appended to its report.[2]

Section 6.—Add the following sentence at the end of this section: "No correction shall be made for emergent stem."

Section 8.—Change the first paragraph to read as follows by the addition of the italicized words and the omission of those in brackets:

> "Use the same method as given under (A) except that glycerin shall be used instead of water, and [that the thermometer shall conform to the following specifications:] *the starting point of the glycerin bath shall be 32° C. (89.6° F.). The bath shall be brought to this temperature and thoroughly agitated, then the apparatus and specimens shall be placed in the bath and the test proceed as usual. In applying the heat, the ring apparatus shall be placed off the center of the container and the burner placed midway between the center and edge of the beaker away from the specimen.*"

Insert a new paragraph after the above, reading as follows:

> "*The thermometer shall conform to the following specifications:*"

Substitute for the present requirements for thermometers, the specifications for high-softening-point thermometer recommended by Committee D-15 on Thermometers and appended to its report.[3]

It is recommended that these revisions be incorporated in the present standard method, preferably without publication as tentative. The committee accordingly asks for the necessary nine-tenths vote for adoption of this revision as standard immediately.

No. 2. *Standard Method of Test for Softening Point of Tar Products* (*Cube-in-Water Method*) (*D 61 - 20*).[1]—The following revision is recommended in this method:

Section 6.—Add the following sentence at the end of this section: "No correction shall be made for emergent stem."

As this change consists merely of the addition of an explanatory sentence, it is recommended that the revision be incorporated in the present standard method without publication as tentative.

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[1] 1921 Book of A.S.T.M. Standards.

[2] See p. 687.—ED.

[3] See p. 689.—ED.

No. 3. *Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 – 23).*[1]—The following revisions are recommended in these specifications:

Section 4.—Omit this section, reading as follows, renumbering the succeeding sections accordingly:

> "The percentage of wear shall be not more than 12.0 per cent."

This change is deemed advisable as the requirement for percentage of wear eliminates a large portion of commercially produced slag which seems to be giving good service, and it is believed that the quality of the product is sufficiently safeguarded by the specification requirement of weight per cubic foot.

Section 6.—Change the last line of this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> "[Retained on] *Passing* 2½-in. screen . . . . not [less] *more* than [85] *15* per cent."

Section 7 (b).—Omit this paragraph which refers to the method of testing the percentage of wear.

It is recommended that these revisions of the standard specifications be published as tentative.

No. 4. *Standard Specifications for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 – 23).*[1]—The following revisions are recommended in these specifications:

Section 4.—Omit this section, reading as follows, renumbering the succeeding sections accordingly, for the same reason stated in connection with Standard Specifications D 65 – 23.

> "The percentage of wear shall be not more than 15 per cent."

Section 6 (b).—Omit this paragraph which refers to the method of testing percentage of wear.

It is recommended that these revisions of the standard specifications be published as tentative.

PROPOSED REVISIONS OF TENTATIVE SPECIFICATIONS AND METHODS OF TEST

No. 1. *Tentative Specifications for Asphalt Cement, 70 to 90 Penetration, for Use in Asphalt Macadam Pavements (D 102 – 23 T).*[2]—In order to harmonize these specifications with the grades of asphalt recommended by a conference called in 1923 by the U. S. Department of Commerce, the following revisions are recommended:

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[1] A.S.T.M. Standards Adopted in 1923.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 728 (1923).

Title.—Change the title to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Tentative Specifications for Asphalt Cement, [70] *85* to [90] *100* Penetration, for Use in Asphalt Macadam Pavements."

Section 1 (*a*).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Penetration at 25° C. (77° F.), 100 g., 5 sec. ....[70] *85* to [90] *100*."

It is recommended that these specifications as revised be continued as tentative.

No. 2. *Tentative Specifications for Asphalt Cement, 90 to 120 Penetration, for Use in Asphalt Macadam Pavements* (*D 103 - 23 T*).[1]—For the same reason stated in connection with Tentative Specifications D 102 - 23 T, the following revisions are recommended:

Title.—Change the title to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Tentative Specifications for Asphalt Cement, [90] *100* to 120 Penetration, for Use in Asphalt Macadam Pavements."

Section 1 (*a*).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Penetration at 25° C. (77° F.), 100 g., 5 sec...........[90] *100* to 120."

It is recommended that these specifications as revised be continued as tentative.

No. 3. *Tentative Specifications for Broken Slag* (*D 159 - 23 T*) (*D 160 - 23 T*) (*D 161 - 23 T*).[2]—For reasons stated in connection with Standard Specifications D 65 - 23 the committee recommends that in each of these tentative specifications Section 4 covering a requirement for percentage of wear be stricken out and the succeeding sections renumbered accordingly. In each specification also strike out the paragraph on "Percentage of Wear" in the section entitled "Methods of Testing."

It is recommended that these specifications as revised be continued as tentative.

No. 4. *Tentative Method of Float Test for Bituminous Road Materials* (*D 139 - 23 T*).[3]—The following revisions are recommended in this method:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 729 (1923).

[2] *Ibid.*, pp. 712–716.

[3] *Ibid.*, p. 756.

Title.—Change the title to read as follows by eliminating the word "Road":

"Tentative Method of Float Test for Bituminous Materials."

This change is recommended at the request of Committee E-1 on Methods of Testing because the test is applicable to other than road materials.

Figure 1.—Change the Weight of Float from "37.95 ± 0.15 g." to "37.90 ± 0.20 g." Change the radius of shoulder from "9.53 mm." to "9.5 mm." Change the diameter of shoulder from "19.05 mm." to "19.0 ± 0.5 mm." Change the outside diameter of rim from "93. ± 1. mm." to "92.0 ± 2.0 mm." Change the weight of collar from "9.95 ± 0.05 g." to "9.80 ± 0.20 g." Change the large inside diameter of collar from "12.80 ± 0.02 mm." to "12.82 ± 0.10 mm." Change the small inside diameter of collar from "9.68 ± 0.02 mm." to "9.70 ± 0.05 mm." Change the thickness of the top and bottom of collar from "1.53 ± 0.01 mm." to "1.40 ± 0.10 mm."

Sections 1 and 2.—Change the weights and dimensions in these two sections to correspond with the changes recommended for Fig. 1.

Section 5.—Place the last two sentences of the second paragraph of Section 5 in a separate paragraph, entitled "Asphalt and Asphalt Products." Then add the following paragraph:

"*Tar Products.*—Tar products shall be poured at a temperature of 100 to 125° C. and immediately immersed in ice water maintained at 5° C. for 5 minutes, after which the surplus material shall be removed by means of a spatula or steel knife, which has been slightly heated. The collar and plate shall then be placed in a tin cup containing ice water maintained at 5° C. ± 1° C., and left in this bath for at least 15 minutes."

Thermometer Specifications.—Committee D-4 referred to Committee D-15 on Thermometers the present thermometer specifications as covered by Section 3, for rearrangement in standard form, with any proposed changes subject to approval of Committee D-4 and now recommends that the present requirements be replaced by the specifications for low softening-point thermometer recommended by Committee D-15 and appended to its report.[1]

It is recommended that this method as revised be continued as tentative.

NO. 5. *Tentative Method of Mechanical Analysis of Subgrade Soils (D 137 - 23 T).*—The following revisions are recommended in this method:

Section 4.—Change to read as follows by the addition of the italicized words and the omission of those in brackets, with the side heading: "Procedure when Determination of Suspension Clay is Required."

"By the method of quartering, a sample weighing approximately 25 g., *prepared as specified in Section 2*, shall be [selected and] placed in a beaker with approximately 500 cc. of distilled water. *This mixture shall be* gradually brought *up* to the boiling point *during a period of one hour* and [shall then be allowed to stand for about 24 hours.] *then allowed to simmer for an additional hour.* [Care should be taken not to boil for more than two or three minutes, as continued boiling tends to cause coagulation.] After standing [for approximately 24 hours,] *until cool,* the material in the beaker shall be thoroughly brushed and dispersed with a stiff brush for two or three minutes and then allowed to stand for eight minutes. The supernatant liquid shall then be decanted to a depth of 8 cm. from the surface of the liquid into a vessel having a capacity of about 10 liters. About 500 cc. of ammoniated water (concentration 1: 500) shall be added to the material remaining in the beaker and the brushing repeated as before. After *again* standing for eight minutes, the supernatant liquid shall be decanted into the large vessel. This process shall be repeated until the supernatant liquid becomes clear after eight minutes sedimentation. The sand and silt [will] have [become] *now been* separated from the clay and suspension clay, which are contained in the large vessel. The material in the beaker shall *then* be transferred to an evaporating dish, dried [in an oven] to constant weight at a temperature [of] *not to exceed* 100° C. (212° F.), cooled and a mechanical analysis made, using 20-*mesh,* [50] *60-mesh,* 100-*mesh* and 200-mesh sieves. [The] Material retained on each sieve shall be recorded as [a] percentage of the original [25-g.] sample, and that which passes the 200-mesh sieve shall be recorded as the percentage of silt in the original sample.

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[1] See p. 687.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 749 (1923).

"The volume of [the] liquid in the large vessel shall *now* be brought up to at least 10 liters by the addition of ammoniated water, and the vessel thoroughly shaken until all material is in suspension. Seventy cubic centimeters *of the liquid* shall then be siphoned from this vessel at a depth of about one-half the total depth of the liquid into each of four centrifuge tubes. The tubes shall then be mounted in the centrifuge and run for 30 minutes at a speed which, for the diameter of the head used, will exert a centrifugal force approximately 500 times the force of gravity. The material which has been thrown out of the liquid by centrifuging shall be classified as clay and that which remains in suspension as suspension clay. The solution containing the suspension clay shall *then* be decanted, evaporated to dryness, and the weight of the suspension clay determined. The clay remaining in the tube shall also be dried and weighed.

"The weight of suspension clay is [determined] *found* from the liquid in four tubes, or 280 cc.; consequently this weight must be multiplied by the factor obtained by dividing the total volume used by 280 cc. in order to obtain the total [amount of] suspension clay in the original [25-g.] sample. The weight of clay is determined from the clay in one tube, or 70 cc.; therefore the total volume divided by 70 cc. gives the factor by which this weight should be multiplied to give the total clay in the original [25 g.] sample. The total weights of clay and suspension clay thus obtained [shall be] *are* converted into percentages of the original 25-g. sample. *The determination of the percentage of suspension clay by this method includes any water-soluble material present which may be determined separately if desired.*"

Add the following new Section 5 with the side heading "Procedure when Determination of Suspension Clay is not Required":

"In case it is not considered necessary to make a determination of the percentage of suspension clay, the following procedure for determination of total clay (clay plus suspension clay) may be followed.

"An aliquot portion of the total volume of water used in washing the sample shall be taken and evaporated to dryness and the weight of clay plus suspension clay obtained, which shall be expressed as the percentage of total clay in the original 25-g. sample."

It is recommended that this method as revised be continued as tentative.

NEW SPECIFICATIONS SUBMITTED AS TENTATIVE

The committee recommends for publication as tentative the following specifications appended hereto:[1]

(*a*) Specifications for Broken Stone for Waterbound Base.
(*b*) Specifications for Broken Stone for Waterbound Macadam Surface Course.
(*c*) Specifications for Broken Stone for Bituminous Macadam.
(*d*) Specifications for Broken Stone for Bituminous Concrete Base.
(*e*) Specifications for Broken Stone for Bituminous Concrete Surface.
(*f*) Specifications for Broken Slag for Bituminous Macadam Base.
(*g*) Specifications for Broken Slag for Bituminous Concrete Base.

These specifications covering broken stone and broken slag for use in waterbound and bituminous types of pavements have been prepared by sectional committees to conform with customary approved requirements of public service bodies and are reasonable from the producers' standpoint. They are in general accord with the latest revisions of existing A.S.T.M. specifications for broken stone and broken slag.

TENTATIVE METHODS OF TEST ADVANCED TO STANDARD

Committee D-4 joins with Committee D-2 on Petroleum Products and Lubricants in recommending the advancement to standard of the Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T).[2]

The committee further endorses the recommendation of Committee D-2 for the advancement to standard of the Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T).

STANDARD METHODS OF TEST WITHDRAWN AS STANDARD

The committee recommends that the following standard methods of test be withdrawn since there are now tentative methods that are intended to replace the standard methods:

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[1] See pp. 902–914.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 694 (1923).

Standard Methods of Test for Quantity of Clay and Silt in Sand for Highway Constrution (D 74 – 21) being superseded by the Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 22 T).

Standard Method of Test for Soluble Bitumen (D 4 – 11) being superseded by the Tentative Method of Test for the Determination of Bitumen (D 4 – 23 T).

The withdrawals of these two standards were balloted upon and approved in 1922 and 1923, respectively, and accordingly were not again submitted to letter ballot.

The results of the letter ballot of the committee upon the recommendations made in this report are as follows:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF EXISTING STANDARDS			
Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (D 36 – 21)	35	0	22
Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 20)	28	5	24
Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 – 23)	33	1	23
Standard Specifications for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 – 23)	33	1	23
II. PROPOSED REVISIONS OF EXISTING TENTATIVE STANDARDS			
Tentative Specifications for Asphalt Cement, 70 to 90 Penetration, for Use in Asphalt Macadam Pavements (D 102 – 23 T)	32	1	24
Tentative Specifications for Asphalt Cement, 90 to 120 Penetration, for Use in Asphalt Macadam Pavements (D 103 – 23 T)	32	1	24
Tentative Specifications for Broken Slag (D 159 – 23 T) (D 160 – 23 T) (D 161 – 23 T)	30	1	26
Tentative Method of Float Test for Bituminous Road Materials (D 139 – 23 T)	35	0	22
Tentative Method of Mechanical Analysis of Subgrade Soils (D 137 – 23 T)	31	0	26
III. PROPOSED NEW TENTATIVE STANDARDS			
Specifications for Broken Stone for Waterbound Base	32	1	24
Specifications for Broken Stone for Waterbound Macadam Surface Course	31	1	25
Specifications for Broken Stone for Bituminous Macadam	31	1	25
Specifications for Broken Stone for Bituminous Concrete Base	32	0	25
Specifications for Broken Stone for Bituminous Concrete Surface	32	0	25
Specifications for Broken Slag for Bituminous Macadam Base	31	1[a]	25
Specifications for Broken Slag for Bituminous Concrete Base	30	2	25
IV. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T)	35	0	22
Endorsement of Recommendations of Committee D-2 on Advaneement of Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T)	35	0	22

This report has been submitted to letter ballot of the committee, which consists of 57 members, of whom 36 have voted affirmatively, none negatively, and 21 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. P. SMITH,
Chairman.

PRÉVOST HUBBARD,
Secretary.

For Addendum to this report, see page 585.—ED.

APPENDIX I

REPORT OF SPECIAL SUB-COMMITTEE, OF COMMITTEE D-4, TO CONSIDER DEFINITIONS FOR SPECIFIC GRAVITY REPORTED BY COMMITTEE E-8[1]

In the recommended definitions for "absolute specific gravity" and "specific gravity," it was felt that the word "substance," suggesting as it did, the idea of the material free from pores or voids, was more appropriate than the word "material" as used by the Sub-Committee on Specific Gravity of Committee E-8 on Nomenclature and Definitions.

The committee likewise felt that the term "specific gravity" should be limited to the determination of the ratio of the weights of the substance and water at the same temperature, whereas the recommendations of the sub-committee of Committee E-8 would allow the use of this term irrespective of the temperatures of either the substance or the water.

The committee felt that wherever the determination of the ratio of weight of substance to the weight of water be taken under conditions at which the temperatures were different, the proper term should be "relative" specific gravity.

In the definition of absolute specific gravity, it was felt that the words "gas free" should be inserted before distilled water.

1. The committee felt that it could not approve recommendation No. 1 as printed in the report of the sub-committee of Committee E-8, because, although the term "density" might be preferred for purely scientific work, long established practice makes it desirable to use the term "specific gravity" in ordinary technical work.

The committee therefore suggests the following definitions in the place of those printed in the report of Committee E-8:

2. *Absolute Specific Gravity* (of solids and liquids).—The ratio of the weight referred to vacua of a given volume of the *substance of the material* at a stated temperature to the weight referred to vacua of an equal volume of *gas free* distilled water at the *same* temperature. It shall be expressed thus:

$$\text{Absolute Specific Gravity } \frac{x^\circ\text{ C.}}{x^\circ\text{ C.}},\ \ldots\ldots\ldots\ldots,$$

3. *Specific Gravity* (of solids and liquids).—The ratio of the weight in air of a given volume of *the substance of the material* at a stated temperature to the

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 534 (1923).

weight in air of an equal volume of distilled water at the *same* temperature. It shall be expressed thus:

$$\text{Specific Gravity } \frac{x^\circ\text{ C.}}{x^\circ\text{ C.}}, \text{.................},$$

4. *Apparent Specific Gravity* (of solids).—The ratio of the weight in air of a given volume of the material, *including naturally occurring gas-filled pores* at a stated temperature to the weight in air of an equal amount of distilled water at the *same* temperature. It shall be expressed thus:

$$\text{Apparent Specific Gravity } \frac{x^\circ\text{ C.}}{x^\circ\text{ C.}}, \text{.................},$$

5. *Relative Specific Gravity.*—The ratio of the weight in air of a given volume of the substance of the material at a stated temperature to the weight in air of an equal volume of distilled water at some other temperature. It shall be expressed thus:

$$\text{Relative Specific Gravity } \frac{x^\circ\text{ C.}}{y^\circ\text{ C.}}, \text{.................},$$

where the temperature above the line is that of the substance of the material and the temperature below the line is the temperature of the water.

6. *Relative Apparent Specific Gravity.*—The ratio of the weight in air of a given volume of the material *including naturally occurring gas-filled pores* at a stated temperature to the weight in air of an equal volume of distilled water at some other temperature. It shall be expressed thus:

$$\text{Relative Apparent Specific Gravity } \frac{x^\circ\text{ C.}}{y^\circ\text{ C.}}, \text{.................},$$

where the temperature above the line is that of the material and the temperature below the line is that of the water.

APPENDIX II

REPORT OF SECTIONAL COMMITTEE ON ASPHALT CONTENT

The committee is not yet ready to offer a method of test as a tentative standard. It is of the opinion that certain features of the evaporation test for residue of a specified penetration require investigation before a tentative method is prepared, and is therefore planning to make a series of cooperative tests during the coming year. Some of the features of the test to which particular attention will be paid are the type of heating bath, size of sample, shape of container, and accuracy of results to be expected. Following is a description of one method to be followed, which will indicate the general method under investigation:

Method for Determination of Asphalt Content

1. *Definition.*—Asphalt content is defined as the residue of a specified penetration at 100 g., 5 seconds, 25° C. (77° F.), obtained by evaporating a road oil or a semi-solid asphalt having a penetration of more than 100, at a temperature of 249 to 260° C. (480 to 500° F.). It shall be determined by the method specified herein, and when the penetration of the residue is not otherwise stated it shall be understood to be 100.

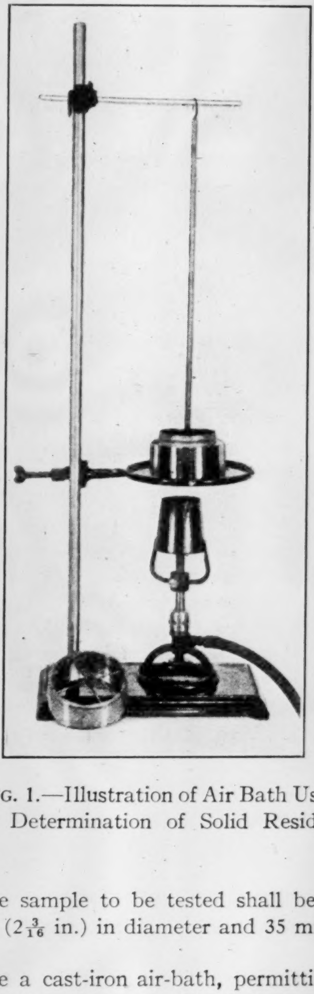

Fig. 1.—Illustration of Air Bath Used in Determination of Solid Residue

APPARATUS

2. *Container.*—The container for holding the sample to be tested shall be a flat-bottom, cylindrical seamless tin box, 55 mm. ($2\frac{3}{16}$ in.) in diameter and 35 mm. ($1\frac{3}{8}$ in.) in depth.

3. *Heating Bath.*—The heating bath shall be a cast-iron air-bath, permitting the immersion of the container to a depth of 1 in. through an opening $\frac{1}{16}$ in. larger than the container. It shall support the container $\frac{1}{4}$ in. above the hot plate and

with at least ¼ in. free air space between the sides of the container and of the air-bath below the opening. A suitable air-bath is shown in Fig. 1.

4. *Hot Plate.*—The air-bath shall be heated upon a suitably mounted hot plate, heated either electrically or by means of a gas flame. The plate shall be capable of maintaining the sample continuously at the required temperature, and shall be provided with the apparatus, rheostat or pressure regulator, necessary to fulfill this requirement.

5. *Thermometer.*—The thermometer shall conform to the following specifications:[1]

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −6 to +400° C. in 2° C. or +20 to +760° F. in 5° F.

TOTAL LENGTH: 303 to 307 mm. (11.92 to 12.08 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, not over 13 mm. (0.51 in.).
Diameter, not greater than stem.

DISTANCE TO −6° C. OR 20° F. LINE FROM BOTTOM OF BULB: 40 to 50 mm. (1.57 to 1.97 in.).

DISTANCE TO 400° C. OR 760° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Red glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10° F. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20°.

IMMERSION: 25 mm. or one inch. The words "1-in. immersion" on Fahrenheit thermometers or "25 mm. immersion" on Centigrade thermometers and a line around the stem 25.4 mm. or 1.00 in. above the bottom of the bulb shall be etched on the thermometer.

SPECIAL MARKING: "A.S.T.M. Open Flash" a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 1° C. up to 372° C. or 2½° F. up to 700° F.

STANDARDIZATION: The thermometer shall be standardized at the ice point and at intervals of approximately 100° F. for 25-mm. or 1-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
100° C.	200° F.	44° C.	110° F.
150° C.	300° F.	54° C.	129° F.
200° C.	400° F.	64° C.	150° F.
250° C.	500° F.	77° C.	175° F.
300° C.	600° F.	91° C.	205° F.
350° C.	700° F.	108° C.	240° F.

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[1] These specifications are the same as for the open cup flash point thermometer, A.S.T.M. Standard Method D 92 – 24.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 to 370° C. or 680 to 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Open Flash, −6 to +400° C." or "A.S.T.M. Open Flash, +20 to +760° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROCEDURE

6. *Preparation of Sample.*—The sample as received shall be thoroughly stirred and agitated, to insure a complete mixture before the portion for testing is removed.

7. *Procedure.*—Fifty grams (50.00 ± 0.10 g.) of the water-free material to be tested shall be weighed into a tared container, which shall then be placed in the air-bath in position to be heated by the hot plate. Support the thermometer in the sample equi-distant from the sides of the container and with the bulb not more than $\frac{1}{4}$ in. above, nor touching the bottom of the container. The bulb shall be completely immersed at all times throughout the test. An assembly of the apparatus is shown in Fig. 1.

8. Heat the sample rapidly to a temperature of 249° C. (480° F.) and during the evaporation maintain this temperature between 249 and 260° C. (480 and 500° F.). The sample shall be stirred with the thermometer from time to time to prevent local overheating and to maintain a homogeneous sample. An experienced operator can judge approximately what percentage of residue he should obtain to secure the desired penetration. When it is supposed that the residue will show the required penetration, the bitumen on the thermometer which may be readily scraped off is returned to the container, which is then removed from the air bath, cooled and weighed. The penetration of the residue shall then be determined in accordance with the Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5) of the American Society for Testing Materials.[1]

9. It frequently is necessary to make several trials before a residue of the required penetration is obtained. If it is found to be greater than that required, all water is removed from the container and the surface of the sample, and the heating and determination of penetration may be repeated as before. A residue shall be considered as satisfactorily obtained when its penetration is within .... of that desired. Its percentage by weight of the original scale is computed, and shall be reported as "percentage of residue of .... penetration," stating the penetration determined upon the sample.

ACCURACY

10. The determination shall be considered as accurate within 1.0 per cent.

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[1] 1921 Book of A.S.T.M. Standards.

APPENDIX III

REPORT OF SECTIONAL COMMITTEE ON DISTILLATION

The Sectional Committee on Distillation desires to give notice that it will recommend a revision next year of the present Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 18).[1] The important points subject to revision are:

1. The rate of distillation;
2. The use of corrected or uncorrected thermometers;
3. The method of handling the residue.

The sectional committee will also consider the possible substitution of a new type of flask that may be found acceptable as well to Committees D-2 on Petroleum Products and Lubricants and D-7 on Timber.

The present dimensions of the flask specified in Methods D 20 are subject to misinterpretations owing to the fact that the present description does not specify whether internal or external dimensions are indicated. It is accordingly recommended that in the reprinting of the Methods D 20 - 18 in the 1924 Book of Standards the original sketch of the flask be reprinted and that the words "external dimensions" be added to the list of dimensions. This is not a change but a clarification of the present method.

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[1] 1921 Book of A.S.T.M. Standards.

ADDENDUM TO REPORT OF COMMITTEE D-4

At a meeting of Committee D-4 held on June 25 it was unanimously voted to recommend to the Society the advancement to standard of the revisions submitted in 1923 of the Standard Methods of Test for Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials (D 55 – 19)[1] and of the revisions submitted in 1922 of the Standard Specifications for Materials for Cement Mortar Bed for Brick, Stone Block and Wood Block Pavements (D 58 – 20).[1] These revisions are published as tentative in the Proceedings of the Society for 1923.[2]

The committee reviewed the various proposed specifications for thermometers, submitted by Committee D-15 on Thermometers, in which the committee is interested. In addition to approving the specifications for low-softening point thermometer and for high-softening point thermometer in connection with their use in Methods D 36 and of the low-softening point thermometer for use in Tentative Methods D 139, as mentioned in the report, the specifications for low-softening point thermometer were approved for incorporation in the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 20).[1] Similarly, the new specifications for high-distillation thermometer were approved for incorporation in the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 18).[1]

The committee approved the recommendation appearing in the Report of the Sectional Committee on Distillation that in reprinting Methods D 20 – 18 in the 1924 Book of A.S.T.M. Standards, a sketch of the flask be included with the statement that the dimensions are outside measurements.

Respectfully submitted,

F. P. Smith,
Chairman.

Prévost Hubbard,
Secretary.

Editorial Note

The proposed revisions of the Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) and for Softening Point of Tar Products (Cube-in-Water Method), recommended in this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards. The proposed revisions of the Standard Specifications for Cement Mortar Bed for Brick, Stone Block and Wood Block Pavements and of the Standard Methods of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, proposed in 1923, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The standards, as revised, appear in the 1924 Book of A.S.T.M. Standards.

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[1] 1921 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, pp. 968–970 (1923).

The proposed revisions of the Standard Specifications for Broken Slag for Waterbound Base and for Shovel-Run or Crusher-Run Broken Slag were accepted for publication as tentative and appear on page 1123.

The proposed revisions of the two Tentative Specifications for Asphalt Cement and the three specifications for Broken Slag, of the Tentative Method of Float Test for Bituminous Road Materials and of the Tentative Method of Mechanical Analysis of Subgrade Soils were approved as recommended in this report. The tentative standards, as thus revised, appear on pages 915–928.

The seven proposed Tentative Specifications for Broken Stone and for Broken Slag, referred to in this report, were accepted for publication as tentative and appear on pages 902–914.

The withdrawal of the Standard Method of Test for Quantity of Clay and Silt in Sand for Highway Construction and of the Standard Method of Test for Soluble Bitumen was approved.

REPORT OF COMMITTEE D-5
ON
COAL AND COKE

The committee has held two meetings during the year, one at Atlantic City on June 25, 1923, the other at Philadelphia on February 6, 1924. It has given careful consideration to changes in its tentative definitions of terms relating to coal and to coke, and has prepared a new method of test for fineness of powdered coal, which is offered for publication as tentative. The work of standardizing a screen test for anthracite sizes is still in the hands of Sub-Committee IV on Standard Sizes and it is hoped that this work will be completed so as to present a method of test next year.

PROPOSED REVISIONS OF STANDARD SPECIFICATIONS AND METHODS OF TEST

1. *Standard Specifications for Foundry Coke (D 17 - 16).*[1]—The committee recommends a slight change in the form of expressing the quantity of sample to be collected. In Sections 3 and 6 of the specifications the quantity of sample is expressed as "2 pecks." It is thought better to substitute "1 cu. ft." for "2 pecks" in these two sections. This revision is one of form only and does not change the substance of the specifications; therefore the committee feels that this minor change can be made without its publication by the Society as a tentative revision.

TENTATIVE REVISIONS OF STANDARDS RECOMMENDED FOR ADOPTION AS STANDARD

2. *Tentative Revisions of Standard Methods of Laboratory Sampling and Analysis of Coal (D 22 - 21).*[1]—Tentative revisions of the Standard Methods of Laboratory Sampling and Analysis of Coal appear on page 970 of Part I of Volume 23 of the *Proceedings* of the American Society for Testing Materials. No criticisms of these tentative revisions have been received. Committee D-5 recommends them to the Society for adoption as standard.

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[1] 1921 Book of A.S.T.M. Standards.

3. *Tentative Revisions of Standard Methods of Laboratory Sampling and Analysis of Coke (D 37 - 21).*[1]—Tentative revisions of the Standard Methods of Laboratory Sampling and Analysis of Coke appear of page 971 of Part I of Volume 23 of the *Proceedings* of the American Society for Testing Materials. No criticisms of these tentative revisions have been received. The committee recommends them to the Society for adoption as standard.

TENTATIVE STANDARDS RECOMMENDED FOR ADOPTION AS STANDARD

4. *Tentative Method of Test for Volume of Cell Space of Lump Coke (D 167 - 23 T).*[2]—There appears to be no reason for continuing this method of test in a tentative status; therefore it is recommended that it be adopted by the Society as standard.

5. *Tentative Specifications for Gas and Coking Coals (D 166 - 23 T).*[3]—It is recommended that these specifications be adopted by the Society as standard.

PROPOSED REVISIONS OF TENTATIVE STANDARDS

6. *Tentative Definitions of Terms Relating to Coke (D 121 - 21 T).*[4]—These definitions have been reviewed by Committee E-8 on Nomenclature and Definitions and a number of changes have been suggested. In the light of these suggestions Sub-Committee II on Nomenclature and Definitions has reviewed the definitions and recommends a number of rewordings. The definitions have accordingly been rewritten and are appended hereto[5] in their proposed revised form. No changes have been made in the definitions for the terms "moisture," "ash," "volatile matter" and "fixed carbon." The definitions are still under consideration and definite revisions of them may be presented next year. No revision has been made in the definition for the term "dry coke" and it is retained in its present form.

The committee recommends that the definitions, as revised, be continued as tentative.

Tentative Definitions of Terms Relating to Coal (D 142 - 22 T).[6]—Of the Tentative Definitions of Terms Relating to Coal, the definitions for the terms "moisture," "volatile matter," "fixed carbon," and "ash" have been given consideration by Committee E-8 and have been assigned with certain suggested revisions to a special sub-committee, which has the terms under consideration. The definition for the term

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[1] 1921 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 766 (1923).

[3] *Ibid.*, p. 763.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 708 (1921).

[5] See p. 934.—ED.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 825 (1922).

"proximate analysis" has been reconsidered and the following revised wording is recommended:

> "*Proximate Analysis.*—In the case of coal, determination by prescribed methods of moisture, volatile matter, fixed carbon (by difference), and ash.
>
> NOTE.—Unless otherwise specified, the term "proximate analysis" does not include determinations of sulfur or phosphorus or any determinations other than those named."

Revisions of the remaining terms are now being given consideration and definite recommendations will be presented next year.

The committee recommends that the definitions, as revised, be continued as tentative.

TABLE I.

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS OF STANDARDS			
Standard Specifications for Foundry Coke (D 17 - 16)	33	0	10
II. TENTATIVE REVISIONS RECOMMENDED FOR ADOPTION AS STANDARD			
Tentative Revisions of Standard Methods of Laboratory Sampling and Analysis of Coal (D 22 - 21)	37	0	6
Tentative Revisions of Standard Methods of Laboratory Sampling and Analysis of Coke (D 37 - 21)	37	0	6
III. TENTATIVE STANDARDS RECOMMENDED FOR ADOPTION AS STANDARD			
Tentative Method of Test for Volume of Cell Space of Lump Coke (D 167 - 23 T)	36	0	7
Tentative Specifications for Gas and Coking Coals (D 166 - 23 T)	37	0	6
IV. PROPOSED REVISIONS OF TENTATIVE DEFINITIONS			
Tentative Definitions of Terms Relating to Coke (D 121 - 21 T)	36	0	7
Tentative Definitions of Terms Relating to Coal (D 142 - 22 T)	37	0	6
V. PROPOSED NEW TENTATIVE STANDARD			
Proposed Tentative Method of Test for Fineness of Powdered Coal	32	0	11

PROPOSED NEW TENTATIVE STANDARD

8. *Proposed Tentative Method of Test for Fineness of Powdered Coal.*—The committee has recognized the desirability of a standard method for the determination of fineness of powdered coal, in order to judge the efficiency of the pulverizing apparatus, and as an indication of the particle size of the coal being burned. The Pittsburgh station of the U. S. Bureau of Mines, in cooperation with eleven other laboratories, carried out the experimental work necessary to obtain data as to the best method of making such fineness tests. The results of this investigative work have been published by the Bureau of Mines as Reports of Investigations, Serial No. 2545, "Determination of the Fineness of Powdered Coal." The method of test as proposed by the committee is based on this experimental work, and also on suggestions to the committee by a number of fuel engineers experienced in the burning of powdered coal. It is recommended that the proposed

Method of Test for Fineness of Powdered Coal, appended hereto,[1] be accepted by the Society for publication as tentative.

The result of the letter ballot vote of the committee, which consists of 43 members, on the recommendations contained in this report is given in Table I.

This report has been submitted to letter ballot of the committee, which consists of 43 members, of whom 34 have voted affirmatively, none negatively, and 9 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.
H. C. PORTER,
Vice-Chairman.

W. A. SELVIG,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Methods of Laboratory Sampling and Analysis of Coal and of the Standard Methods of Laboratory Sampling and Analysis of Coke, proposed in 1922, were approved at the annual meeting, as recommended in this report, and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Method of Test for Volume of Cell Space of Lump Coke and the Tentative Specifications for Gas and Coking Coals, referred to in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924, and appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Definitions of Terms Relating to Coke and of the Tentative Definitions of Terms Relating to Coal, recommended in this report, were accepted. The definitions, as thus revised, appear on pages 934–938.

The proposed Tentative Method of Test for Fineness of Powdered Coal, referred to in this report, was accepted for publication as tentative and appears on page 929.

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[1] See p. 929.—ED.

REPORT OF COMMITTEE D-7
ON
TIMBER

During the past year Committee D-7 on Timber has continued its investigations conducted under the auspices of the Central Committee on Lumber Standards. It was represented at the third general lumber conference called by Secretary Hoover at Washington on December 12 and 13, 1923, at which time simplified practice recommendations with respect to the general classification of lumber were adopted by this general conference. Most of the matter adopted deals with what is commonly known as yard lumber. Committee D-7 in reviewing the recommendations made at the Washington conference endorsed these recommendations as marking much progress in lumber standardization, but this endorsement is qualified as to detail. The committee proposes to use some of the basic principles agreed on in connection with future developments in proposing standard specifications for structural timbers.

During the past year, representatives of Committee D-7 have attended frequent sessions of the Consulting Committee of the Central Committee and have kept in touch with developments, most of which, however, have not yet reached a point where they are ready for definite action by this Society.

The committee still has three tentative standards, all of which are recommended to be continued as tentative. They are as follows:

Tentative Specifications for Structural Douglas Fir (D 23 - 20 T). These specifications must still remain as tentative in view of the proposed fundamental changes in writing rules for grading structural timbers, as indicated in the report of Sub-Committee I on Specifications for Timber, appended hereto.

Tentative Methods of Testing Small Clear Specimens of Timber (D 143 - 22 T). This is a subject which is still being vigorously developed, as indicated in the report of Sub-Committee IX on Methods of Testing.

Tentative Method of Test for Coke Residue of Creosote Oil (D 168 - 23 T). As indicated in the report of Sub-Committee VI, these specifications are to remain tentative because of further coöperative work with other committees of this Society.

Sub-Committee I on Specifications for Timber has a carefully digested report attached hereto, which is submitted as information. Specific attention is called to the new principles embodied in this report. These principles are the result after a careful study of tests made by the U. S. Forest Service, and credit is herewith given to the U. S. Forest Service for valuable assistance.

Sub-Committee VI on Timber Preservatives has held two meetings during the year. A report of the sub-committee is appended hereto and includes proposed Tentative Methods of Chemical Analysis of Zinc Chloride, a revision of the Standard Methods of Sampling and Analysis of Creosote Oil, involving the float test of residue, a revision of the specifications for distillation thermometer in accordance with the recommendation of Committee D-15 on Thermometers, and another regarding distillation vessel for creosote oil and other high boiling materials.

In presenting the Tentative Methods of Analysis of Zinc Chloride, which are recommended by the committee for publication as tentative, the committee recognizes the imperfection of these methods in not including specifications for sampling. This matter has long been a subject of discussion and investigation by producers and users of zinc chloride and it is conceded that the accurate sampling of fused zinc chloride is a very difficult matter. It is hoped that some agreement on this question will be arrived at later.

Committee D-7, on the recommendation of Sub-Committee VI, has endorsed the report of the special committee of Committee D-4 on Road and Paving Materials in reference to Specific Gravity, prepared in answer to a circular communication on the subject from Committee E-8 on Nomenclature and Definitions.

The committee has also approved the Sub-Committee's recommendation that the Tentative Method of Test for Coke Residue of Creosote Oil (D 168 – 23 T)[1] be continued as tentative.

The proposed Tentative Methods of Chemical Analysis of Zinc Chloride was referred to letter ballot of the committee, which consists of 26 members, of whom 16 have voted affirmatively; none negatively; and 10 have refrained from voting.

Sub-Committee IX on Methods of Testing has been engaged during the past year in the consideration of revisions of the Tentative Methods of Testing Small Clear Specimens of Timber (D 143 – 22 T)[2] and the preparation of a new procedure entitled Tentative Methods for Conducting Static Tests of Timber in Structural Sizes. This work has actually been done by the Sectional Committee on Methods of Testing Wood, which is sponsored by this Society and the U. S. Forest Service under the rules of the American Engineering Standards Committee and upon which Committee D-7 is represented through the membership of Sub-Committee IX. A report of Sub-Committee IX outlining these activities is appended, as well as proposed revisions in the Tentative Methods D 143 and the proposed Tentative Methods for Conducting Static Tests. Committee D-7 recommends that these be published by the Society as tentative.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 771 (1923).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 827 (1922).

The revisions of D 143 - 22 T were submitted to letter ballot of the committee, which consists of 26 members, of whom 22 have voted affirmatively, none negatively, and 4 have refrained from voting.

The "Tentative Methods for Conducting Static Tests of Timbers in Structural Sizes" was submitted to letter ballot of the committee, which consists of 26 members, of whom 22 have voted affirmatively, none negatively, and 4 have refrained from voting.

This report has been submitted to letter ballot of the committee, which consists of 26 members, of whom 19 have voted affirmatively, none negatively, and 7 have refrained from voting.

Respectfully submitted on behalf of the committee,

HERMANN VON SCHRENK,
Chairman.

J. A. NEWLIN,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Methods of Sampling and Analysis of Creosote Oil, recommended in this report, were approved at the annual meeting by nine-tenths vote and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Methods of Testing Small Clear Specimens of Timber were approved, as recommended in this report. The tentative methods, as thus revised, appear on page 939.

The proposed Tentative Methods of Analysis of Zinc Chloride and the proposed Tentative Methods for Conducting Static Tests of Timbers in Structural Sizes were accepted for publication as tentative and appear on pages 976–998.

REPORT OF SUB-COMMITTEE 1 ON SPECIFICATIONS FOR TIMBER

The Society at the present time has two standard specifications for southern yellow pine structural timbers, one for timbers to be used untreated,[1] and another for southern pine timbers to be creosoted.[2] There is also a tentative specification for Douglas fir timbers.[3] These specifications were the outcome of investigations which started early in 1905. As indicated in the 1905 report of the committee:[4] "Grading as now understood consists essentially in the specification of three factors:

(*a*) A definition of standard defects and to what extent these defects shall be admitted into various grades;

(*b*) A determination of sizes, that is, length, width and thickness;

(*c*) In certain instances, the functions to which the material is to be put are to be specified."

On this basis, the present standard and tentative specifications for structural timbers were drawn. As the result of a comprehensive study of many thousand tests the U. S. Forest Service has recently recommended a revision of these specifications for structural timbers. This revision is based upon a better understanding as to the influence of various defects on allowable stresses for timbers, under varying conditions of use. The Forest Service has suggested an approved basis for grading which consists in a closer correlation between existing defects and strength.

The sub-committee during the past year has given serious study to these recommendations. After a detailed analysis the general scheme employed in this basis for grading has been somewhat modified to adapt it to modern conditions of manufacture and use. The sub-committee herewith presents the results of its investigations in the form of information. The subject has been divided into:

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[1] Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (Serial Designation: D 10 - 15), 1921 Book of A.S.T.M. Standards.

[2] Standard Specifications for Southern Yellow-Pine Timber to be Creosoted (Serial Designation: D 24 - 20), 1921 Book of A.S.T.M. Standards.

[3] Tentative Specifications for Structural Douglas Fir (Serial Designation: D 23 - 20 T), *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 704 (1920); also 1923 Book of A.S.T.M. Tentative Standards, p. 529.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. V, p. 148 (1905).

(*a*) The basis for grading;

(*b*) Suggested grades for Douglas fir and southern pine structural timbers, using the new basis in the establishment of these grades;

(*c*) A suggested outline correlating these suggested grades with the functions to which the material is to be put.

FACTORS WHICH AFFECT STRENGTH OF TIMBERS

The most important factors which influence the strength of structural timbers are rate of growth, density (or dry weight), moisture content, size and position of knots, amount of shakes or checks, angle of grain, amount of wane, etc. These factors must all be considered in design and grading if the maximum utilization is to be obtained from the material used.

RATE OF GROWTH

Medium or normal rate of growth is required in the Standard and Select Common grades in order to eliminate material of exceptionally rapid or exceptionally slow growth in these grades. The method of measuring the ring count on the cross-section of such timbers is described in the Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (D 10 – 15) for southern pine and in the Tentative Specifications for Structural Douglas Fir (D 23 – 20 T) for Douglas fir.[1]

DENSITY

The density of wood substance of all species is practically the same. The dry weight is therefore a measure of the amount of wood substance present; and on the amount of wood substance present depends the strength of clear wood. In some species the density may be estimated by the proportion of summer wood present, summer wood in softwoods being the heavy, dark portion of the annual growth layers. The percentage of this heavy, dark wood present furnishes a practical means of grading for strength of southern yellow pine and Douglas fir, two of the most important species used as structural timbers. Timbers from these species are divided into three classes, designated as dense, medium and exceptionally light. The division is made by a visual inspection of the end grain, a method devised by the Forest Service and adopted by the American Society for Testing Materials.

Specifications for determination of density in Douglas fir and southern pine are given in the two specifications previously mentioned.

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[1] *Loc. cit.*

MOISTURE

Moisture affects the strength of structural timbers both directly and indirectly. The direct effect of loss of moisture is the stiffening and strengthening of the wood fibers. This increase in strength, however, is accompanied by checking, splitting, warping and twisting; as a consequence, some of the strength due to drying is lost.

In the poor grades of dimension 4 in. and under in thickness and in large structural timbers, this loss approximately equals the increase resulting from drying. On the other hand, with the better grades of dimension the increase due to drying exceeds the increased injury resulting from defects. Working stresses for dimension 4 in. and under in thickness to be used in dry interior construction may therefore be increased proportionally over those for large timbers with corresponding defects from equal stresses in a grade having one-half the strength of clear wood to stresses 25 per cent greater on a grade of the clear wood strength.

DEFECTS

Defects are any irregularities occuring in or on wood that may lower some of its strength properties. The strength of wood is dependent more upon the size, number and location of defects than upon the species or density. Defects are divided into two groups: (1) those which materially affect the strength and must be considered in strength rules; and (2) those which would normally be excluded for other reasons than their effect on strength in extreme fiber and strength in shear. The first group includes knots, decay, shakes, checks, splits, and cross-grain; and the grading rules definitely limit the size allowable in each grade. The second group relates to percentage of heartwood, sapwood, defects in manufacture, etc. Requirements for these are given when they are desired as special provisions in use of the material.

Knots and Knot Holes.—On the basis of effect on strength, the various kinds of knot defects are classified into three groups—sound knots and knot holes, unsound knots, and cluster knots. No distinction is made between knots and knot holes, for observation in recent tests has shown that intergrown knots are fully as injurious to the strength as knot holes or incased knots of the same size. This is because of the greater distortion of the grain which occurs around the intergrown knots.

The effect on strength of the shape of a knot, such as round, oval, spike, or branch, has been taken care of in the method prescribed in the rules for measuring the knots. Cluster knots which consist of two or more knots grouped together as a unit with the fibers of the wood deflected around the entire unit, are prohibited, except in the lowest grade, because their diameter is not a good indication of the effect they may have on the strength.

The measurement of knots or knot holes is made on the section of the knot or knot hole appearing in the surface in question. The diameter of a knot on the narrow or horizontal face is taken as the width of the knot between lines parallel to the edges of the timber. On the wide or vertical face the smallest dimension of a knot is taken. Knots on the edge of wide faces are limited to the same size as on the adjacent portion of the narrow faces. Cluster knots occurring on any face in any part of a beam should cause its rejection, except when specifically permitted. The diameter of cluster knots should be measured between lines enclosing the cluster. Knots in dimension 4 in. and under in thickness are measured as of their average dimension.

Timbers used in moist or wet locations favorable to decay in wood should not contain knot holes where moisture may collect.

Shakes, Checks and Splits.—Shakes reduce the area acting in resistance to shear, and the limitations placed on shakes are therefore based on this reduction. Whether a shake appears on a face or is boxed does not influence the shear area affected and therefore is not important from a strength standpoint. Shakes appearing on the surface are permitted, but where any special use to which a timber is to be put is such as to make shakes appearing on the surface undesirable, they should be excluded on that basis.

The width of shakes is taken as the distance between lines parallel to the vertical edges of a timber.

Checks are prohibited on the same basis as shakes, which is the reduction in the shear area.

Checks, or a combination of checks with shakes, which would reduce the strength to a greater extent than the allowable round shake, should not be permitted.

Splits should be classified as checks or shakes and graded as such.

Cross-Grain.—The limits placed on cross-grain are based on the results of a detailed study of the effect of cross-grain and spiral grain upon the strength, and the weakening of material by checks which invariably develop and which, without exception, follow the grain.

Wane.—Wane is limited by such considerations as bearing area, nailing edge, appearance, fire hazard, etc.; and any limitation for these reasons is sufficient to insure material which is not weakened to a greater extent than will result from the allowable knots. When wane occurs at or near a knot, the combined effect must not be greater than that of the maximum allowable knot.

SPECIAL REQUIREMENTS

Heartwood.—When durability under exposure is a factor, a heartwood requirement should be provided in specific use grades according to use, exposure and species.

Sapwood.—When material is to be given preservative treatment a sapwood requirement should be provided according to use, type of treatment and species.

When strength alone is the controlling factor no requirement or limitation of heartwood or sapwood is needed, as they are of equal strength.

Square Edge.—When appearance or use require full sections or square corners, square edges should be specified in specific use grades.

STANDARDS OF LUMBER QUALITY (ALL SPECIES)

Timbers and lumber of all species used for load-bearing purposes in construction may be divided into two general classes:

1. Standard;
2. Common.

Standard timbers may be further classified as Dense Standard. This sub-classification contains the highest type of structural timber commercially obtainable, and is specified for use where exceptional strength, minimum size for a given purpose, or maximum durability, is required. This material will be used most frequently in the mill-construction type of building where heavy floor loads are present, in bridges or trestle members under heavy load, or in truss members, derricks, etc.

The variation in these basic classes depends mainly on rate of growth, density requirements, and the size and location of ordinary defects such as knots, shakes, angle of grain and wane.

Structural timbers, including material 6 in. and larger in thickness and width, are graded by a different set of limitations on defects than in the case of dimension and heavy joists less than 6 in. in thickness. Heavy joists thicker than 4 in. should be graded as structural timbers.

In dimension and heavy joists, the two general classes, Standard and Common, are represented in the standard yard grades, Select Common and No. 1 Common, respectively.

BASIC GRADES AS APPLIED TO DOUGLAS FIR AND SOUTHERN PINE

I. STANDARD GRADE TIMBERS

1. Douglas fir or southern pine timbers shall show not less than 6 rings per inch and not more than 20 rings per inch when measured over the same portion of cross-section as prescribed for density determination in the Tentative Specifications for Structural Douglas Fir (D 23 – 20 T)[1] for Douglas fir and in the Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (D 10 – 15)[2] for southern pine.

BEAMS AND STRINGERS

Basic Provisions

2. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed the width of the face on which they occur.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

Width of Face, in.	Maximum Size of Knots, in.	
	Narrow Face and Corner	Center Line Wide Face
6	1½	1½
8	1¾	2
10	2	2½
12	2⅛	3
14	2¼	3¼
16	2½	3½
18	2⅝	3¾
20	2¾	4
22	2⅞	4⅛
24	3	4¼

Increase in size of knot on wide face is proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

3. *Shakes.*—The maximum width of shakes shall be as follows:

Width of Face, in.	Maximum Width of Shakes, in.	
	Green	Seasoned
6	1½	2
8	2	2⅝
10	2½	3¼
12	3	4
14	3½	4⅝
16	4	5¼
18	4½	6
20	5	6⅝
22	5½	7¼
24	6	8

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 704 (1920); also 1923 Book of A.S.T.M. Tentative Standards, p. 529. These specifications will hereafter be referred to in the abbreviated form: A.S.T.M. Specifications D 23 – 20 T.

[2] 1921 Book of A.S.T.M. Standards. These specifications will hereafter be referred to in the abbreviated form: A.S.T.M. Specifications D 10 – 15.

4. *Angle of Grain.*—The angle of grain shall not exceed 1 in 15.

5. *Wane.*—The wane shall not exceed one-eighth of the width of the narrow face.

Special Provisions

6. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 – 20 T for Douglas fir and A.S.T.M. Specifications D 10 – 15 for southern pine.

7. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See Standard Specifications for Southern Yellow-Pine Timber to be Creosoted (Serial Designation: D 24 – 20) of the American Society for Testing Materials.[1]

8. *Square Edge.*—When appearance or bearing are factors, square edge timbers should be specified.

POSTS AND SQUARE TIMBERS

Basic Provisions

9. *Knots, Maximum Size.*—The maximum size of knots shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM SIZE OF KNOTS, IN
6	$1\frac{1}{2}$
8	2
10	$2\frac{1}{2}$
12	3
14	$3\frac{1}{4}$
16	$3\frac{1}{2}$
18	$3\frac{3}{4}$
20	4
22	$4\frac{1}{8}$
24	$4\frac{1}{4}$

10. *Shakes.*—The maximum width of shakes shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM WIDTH OF SHAKES, IN.	
	GREEN	SEASONED
6	$2\frac{1}{2}$	3
8	$3\frac{1}{2}$	4
10	4	5
12	$4\frac{3}{4}$	6
14	$5\frac{1}{2}$	7
16	$6\frac{1}{2}$	8
18	$7\frac{1}{4}$	9
20	8	10
22	$8\frac{3}{4}$	11
24	$9\frac{1}{2}$	12

11. *Angle of Grain.*—The angle of grain shall not exceed 1 in 10.

12. *Wane.*—The wane shall not exceed one-eighth of the width of the face.

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[1] 1921 Book of A.S.T.M. Standards. These specifications will hereafter be referred to in the abbreviated form: A.S.T.M. Specifications D 24 – 20.

Special Provisions

13. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 75 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 – 20 T for Douglas fir and A.S.T.M. Specifications D 10 – 15 for southern pine.

14. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 – 20.

15. *Square Edge.*—When appearance is a factor, square-edge timbers should be specified.

II. DENSE STANDARD GRADE TIMBERS

16. Douglas fir or southern pine timbers shall meet the specifications for density as prescribed in A.S.T.M. Specifications D 23 – 20 T and D 10 – 15, respectively.

BEAMS AND STRINGERS

Basic Provisions

17. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed the width of the face on which they occur.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM SIZE OF KNOTS, IN.	
	NARROW FACE AND CORNER	CENTER LINE WIDE FACE
6	1½	1½
8	1¾	2
10	2	2½
12	2⅛	3
14	2¼	3¼
16	2½	3½
18	2⅝	3¾
20	2¾	4
22	2⅞	4⅛
24	3	4¼

Increase in size of knot on wide face is proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

18. *Shakes.*—The maximum width of shakes shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM WIDTH OF SHAKES, IN.	
	GREEN	SEASONED
6	1½	2
8	2	2⅝
10	2½	3¼
12	3	4
14	3½	4⅝
16	4	5¼
18	4½	6
20	5	6⅝
22	5½	7¼
24	6	8

19. *Angle of Grain.*—The angle of grain shall not exceed 1 in 15.

20. *Wane.*—The wane shall not exceed one-eighth of the width of the narrow face.

Special Provisions

21. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 – 20 T for Douglas fir and A.S.T.M. Specifications D 10 – 15 for southern pine.

22. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 – 20.

23. *Square Edge.*—When appearance or bearing are factors, square edge timbers should be specified.

POSTS AND SQUARE TIMBERS

Basic Provisions

24. *Knots, Maximum Size.*—The maximum size of knots shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM SIZE OF KNOTS, IN.
6	1½
8	2
10	2½
12	3
14	3¼
16	3½
18	3¾
20	4
22	4⅛
24	4¼

25. *Shakes.*—The maximum width of shakes shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM WIDTH OF SHAKES, IN.	
	GREEN	SEASONED
6	2½	3
8	3½	4
10	4	5
12	4¾	6
14	5½	7
16	6½	8
18	7¼	9
20	8	10
22	8¾	11
24	9½	12

26. *Angle of Grain.*—The angle of grain shall not exceed 1 in 10.

27. *Wane.*—The wane shall not exceed one-eighth of the width of the face.

Special Provisions

28. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 75 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 - 20 T for Douglas fir and A.S.T.M. Specifications D 10 - 15 for southern pine.

29. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 - 20.

30. *Square Edge.*—When appearance is a factor, square-edge timbers should be specified.

III. COMMON GRADE TIMBERS

31. Douglas fir or southern pine timbers.

BEAMS AND STRINGERS

Basic Provisions

32. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed $1\frac{1}{2}$ times the width of the face on which they occur.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

Width of Face, in.	Maximum Size of Knots, in. Narrow Face and Corner	Maximum Size of Knots, in. Center Line Wide Face
6	$2\frac{1}{2}$	$2\frac{1}{2}$
8	$2\frac{7}{8}$	$3\frac{1}{4}$
10	$3\frac{1}{4}$	4
12	$3\frac{1}{2}$	5
14	$3\frac{3}{4}$	$5\frac{1}{2}$
16	4	$5\frac{3}{4}$
18	$4\frac{1}{4}$	$6\frac{1}{4}$
20	$4\frac{1}{2}$	$6\frac{1}{2}$
22	$4\frac{3}{4}$	$6\frac{3}{4}$
24	5	7

Increase in size of knot on wide face is proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

33. *Shakes.*—The maximum width of shakes shall be as follows:

Width of Face, in.	Maximum Width of Shakes, in. Green	Maximum Width of Shakes, in. Seasoned
6	$2\frac{1}{2}$	3
8	$3\frac{1}{4}$	4
10	4	5
12	5	6
14	$5\frac{1}{2}$	7
16	$6\frac{1}{2}$	8
18	$7\frac{1}{4}$	9
20	8	10
22	$8\frac{3}{4}$	11
24	$9\frac{1}{2}$	12

34. *Angle of Grain.*—The angle of grain shall not exceed 1 in 10.

35. *Wane.*—The wane shall not exceed one-fourth of the width of the narrow face.

Special Provisions

36. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 - 20 T for Douglas fir and A.S.T.M. Specifications D 10 - 15 for southern pine.

37. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 - 20.

38. *Square Edge.*—When appearance or bearing are factors, square-edge timbers should be specified.

POSTS AND SQUARE TIMBERS

Basic Provisions

39. *Knots, Maximum Size.*—The maximum size of knots shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM SIZE OF KNOT, IN.
6	$2\frac{1}{2}$
8	$3\frac{1}{4}$
10	4
12	5
14	$5\frac{1}{2}$
16	$5\frac{7}{8}$
18	$6\frac{1}{4}$
20	$6\frac{1}{2}$
22	$6\frac{3}{4}$
24	7

40. *Shakes.*—The maximum width of shakes shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM WIDTH OF SHAKES, IN.	
	GREEN	SEASONED
6	3	$3\frac{1}{2}$
8	4	$4\frac{3}{4}$
10	5	6
12	6	$7\frac{1}{4}$
14	7	$8\frac{1}{2}$
16	8	$9\frac{1}{2}$
18	9	$10\frac{3}{4}$
20	10	12
22	11	$13\frac{1}{4}$
24	12	$14\frac{1}{2}$

41. *Angle of Grain.*—The angle of grain shall not exceed 1 in 8.

42. *Wane.*—The wane shall not exceed one-fourth of the width of the face.

Special Provisions

43. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 75 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 - 20 T for Douglas fir and A.S.T.M. Specifications D 10 - 15 for southern pine.

44. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 – 20.

45. *Square Edge.*—When appearance is a factor, square-edge timbers should be specified.

IV. SELECT COMMON GRADE DIMENSION

46. Douglas fir or southern pine in this grade is comparable in class to Standard Grade in timbers. Such material shall show not less than six rings per inch and not more than twenty rings per inch when measured over the same portion of cross-section as prescribed for density determinations in A.S.T.M. Specifications D 23 – 20 T for Douglas fir, or in A.S.T.M. Specifications D 10 – 15 for southern pine.

Dimension thicker than 4 in. shall be graded in accordance with structural grades for beams and stringers in timbers.

Basic Provisions

47. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed the width of the face on which they occur. Knots on the wide face of dimension are measured as of their average diameter. Knots on narrow faces of boxed heart dimension shall be limited as in structural grades for timbers.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

WIDTH OF FACE, IN.	MAXIMUM SIZE OF KNOTS, IN. ON OR NEAR EDGE	MAXIMUM SIZE OF KNOTS, IN. CENTER LINE WIDE FACE
4	$\frac{3}{4}$	$1\frac{3}{8}$
6	$1\frac{1}{8}$	2
8	$1\frac{1}{2}$	$2\frac{5}{8}$
10	$1\frac{7}{8}$	$3\frac{3}{8}$
12	$2\frac{1}{4}$	4
14	$2\frac{3}{8}$	$4\frac{3}{8}$
16	$2\frac{1}{2}$	$4\frac{5}{8}$

Increase in size of knot on wide face is proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

48. *Shakes and Checks.*—Shakes with barely perceptible opening shall be allowed. Surface checks shall not be more than $\frac{1}{32}$ in. wide nor more than 10 in. long. The length of splits shall not exceed either the width of the piece nor one-sixth of its length.

49. *Angle of Grain.*—The angle of grain shall not exceed 1 in 12.

50. *Wane.*—The wane shall not exceed $\frac{1}{2}$ in. on a face nor one-fourth the thickness and one-sixth the length of the piece.

Special Provisions

51. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 – 20 T for Douglas fir and A.S.T.M. Specifications D 10 – 15 for southern pine.

52. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 – 20.

53. *Square Edge.*—When appearance or bearing are factors, square-edge timbers should be specified.

V. DENSE SELECT COMMON GRADE DIMENSION

54. Douglas fir or southern pine dimension shall meet the specifications for density as prescribed in A.S.T.M. Specifications D 23 - 20 T and D 10 - 15, respectively.

Basic Provisions

55. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed the width of the face on which they occur. Knots on the wide face of dimension are measured as of their average diameter. Knots on narrow faces of boxed heart dimension shall be limited as in structural grades for timbers.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

Width of Face, in.	Maximum Size of Knots, in.	
	On or Near Edge	Center Line Wide Face
4	$\frac{3}{4}$	$1\frac{3}{8}$
6	$1\frac{1}{8}$	2
8	$1\frac{1}{2}$	$2\frac{5}{8}$
10	$1\frac{7}{8}$	$3\frac{3}{8}$
12	$2\frac{1}{4}$	4
14	$2\frac{3}{8}$	$4\frac{3}{8}$
16	$2\frac{1}{2}$	$4\frac{5}{8}$

Increase in size of knot on wide face if proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

56. *Shakes and Checks.*—Shakes with barely perceptible opening shall be allowed. Surface checks shall not be more than $\frac{1}{32}$ in. wide nor more than 10 in. long. This length of splits shall not exceed either the width of the piece nor one-sixth of its length.

57. *Angle of Grain.*—The angle of grain shall not exceed 1 in 12.

58. *Wane.*—The wane shall not exceed $\frac{1}{2}$ in. on a face nor one-fourth the thickness and one-sixth the length of the piece.

Special Provisions

59. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 - 20 T for Douglas fir and A.S.T.M. Specifications D 10 - 15 for southern pine.

60. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 - 20.

61. *Square Edge.*—When appearance or bearing are factors, square-edge timbers should be specified.

VI. NO. 1 COMMON GRADE DIMENSION

62. Douglas fir or southern pine dimension. Dimension thicker than 4 in. shall be graded in accordance with structural grades for beams and stringers in timbers.

Basic Provisions

63. *Knots.* (*a*) *General.*—The sum of the diameters of all knots within the center half of the length of a beam shall not exceed $1\frac{1}{2}$ times the width of the face on which they occur. Knots on narrow faces of boxed heart dimension shall be limited as in structural grades for timbers.

(*b*) *Maximum Size.*—The maximum size of knots shall be as follows:

Width of Face, in.	Maximum Size of Knots, in. On or Near Edge	Maximum Size of Knots, in. Center Line Wide Face
4	1	$1\frac{3}{4}$
6	$1\frac{1}{2}$	$2\frac{1}{2}$
8	2	$3\frac{1}{2}$
10	$2\frac{1}{2}$	$4\frac{3}{8}$
12	3	$5\frac{1}{4}$
14	$3\frac{1}{4}$	$5\frac{5}{8}$
16	$3\frac{1}{2}$	6

Increase in size of knot on wide face is proportional to distance of center line of knot from edge of wide face, to a maximum at the center line of wide face.

64. *Shakes and Checks.*—Shakes shall not be more than $\frac{1}{32}$ in. wide, shall not go through the piece, and their length shall not exceed the width of the piece. Surface checks will be allowed. The length of splits shall not exceed either the width of the piece nor one-sixth of its length.

65. *Angle of Grain.*—The angle of grain shall not exceed 1 in 10.

66. *Wane.*—The wane shall not exceed $\frac{3}{4}$ in. on a face nor one-fourth the thickness and one-third the length of the piece.

Special Provisions

67. *Heartwood.*—When resistance to decay without preservative treatment is a factor, 85 per cent heart on each of the four sides should be specified. See A.S.T.M. Specifications D 23 – 20 T for Douglas fir and A.S.T.M. Specifications D 10 – 15 for southern pine.

68. *Sapwood.*—When preservative treatment is to be applied, 30 per cent sapwood in cross-section should be specified. See A.S.T.M. Specifications D 24 – 20.

69. *Square Edge.*—When appearance or bearing are factors, square edges should be specified.

USE SPECIFICATIONS FOR TIMBER AND LUMBER (LOAD BEARING)

The quality of timbers or lumber best suited for load-bearing uses in a given structure varies with the kind and amount of load and the liability of deterioration by decay. Safety in design, resistance to decay and economy in cost may be regulated by a study of the use of the structure and its degree of exposure.

Grades of timbers may be specified in any case to meet any of three use viewpoints:

1. Load carrying capacity, which will mean the use of Standard, Dense Standard, or Common timbers, depending upon the loads to be carried and space limitations.

2. Decay resistance, which places a heartwood requirement on any of these three grades of timbers if they are to be used in damp or exposed locations without preservative treatment, or a sapwood requirement if they are to be treated.

3. A combination of 1 and 2.

Where details of design will permit, it may be possible to substitute grades lower than specified in the Use Specifications which follow, allowing the increased size of the member of lower strength quality to fulfill the requirements of strength. This does not alter the need for heartwood or sapwood requirements. While there is no difference in strength between heartwood and sapwood, each has its function in resisting decay or aiding preservative treatment.

In a similar manner, treated timbers of low strength quality often may be used in locations where heartwood timbers of higher quality and cost would be used.

When appearance is a factor, square edge timbers should be specified.

TYPES OF STRUCTURES

Load-bearing structures may be classified under the following general divisions:

A. Buildings;
B. Bridges and Trestles;
C. Docks, Piers and Wharves;
D. Platforms;
E. Gates, Bins, Bulkheads and Sheet Piling;
F. Cars;
G. Barges;
H. Transmission Lines;
I. Track;
J. False Work and Temporary Construction;
K. Mine Supports.

In addition to these general divisions, there are many auxiliary uses for timbers and lumber where isolated members form a part of the general structure. The importance of these members may be great and may warrant a Use Specification in many cases; but in general these cases will be covered by the specifications for members forming parts of the general divisions shown above, where such members are used under similar stress and exposure conditions.

There are given below two suggested use specifications covering the first two classifications of the above types of structures, namely, buildings (mill construction type) and bridges and trestles. The committee is now engaged in developing use specifications for other classes of structures listed above.

USE SPECIFICATIONS (A): BUILDINGS

(MILL CONSTRUCTION TYPE)

I. HEAVY LOADING

(LIVE FLOOR LOAD OVER 200 LB. PER SQ. FT.)

Girders.—Dense Standard Grade Douglas fir or southern pine.

Beams.—Dense Standard Grade Douglas fir or southern pine.

Posts.—Standard Grade Douglas fir or southern pine.

Sub-Floor.—Standard Grade Douglas fir or southern pine.

Roof Plank.—Common Grade Douglas fir or southern pine.

II. MEDIUM LOADING

(LIVE FLOOR LOAD 200 LB. PER SQ. FT. AND UNDER)

Girders.—Standard Grade Douglas fir or southern pine.

Beams.—Standard Grade Douglas fir or southern pine.

Posts.—Common Grade Douglas fir or southern pine.

Sub-Floor.—Common Grade Douglas fir or southern pine.

Roof Plank.—Common Grade Douglas fir or southern pine.

NOTE.—In cases of extreme moisture or where manufacturing processes are likely to favor decay, a heartwood requirement should be included unless a recognized preservative treatment is applied to the grades named, when a sapwood requirement should be included. For details, see reference in various grades.

USE SPECIFICATIONS (B): BRIDGES AND TRESTLES

I. HEAVY LOADING, RAILWAY

(COOPER'S CLASS E-60 AND ABOVE)

Stringers.—Dense Standard Grade Douglas fir or southern pine.

Caps.—Standard Grade Douglas fir or southern pine.

Posts.—Standard Grade Douglas fir or southern pine.

Sills.—Common Grade Douglas fir or southern pine.

Braces.—Standard Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Longitudinal Struts or Girts.—Standard Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Bridge Ties.—Standard Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

II. MEDIUM LOADING, RAILWAY OR HIGHWAY

(BELOW COOPER'S CLASS E-60)

Stringers.—Standard Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Caps.—Standard Grade Douglas fir or southern pine.

Posts.—Common Grade Douglas fir or southern pine.

Sills.—Common Grade Douglas fir or southern pine.

Braces.—Common Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Longitudinal Struts or Girts.—Common Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Bridge Ties.—Common Grade Douglas fir or southern pine. Heartwood requirement or preservative treatment.

Planking.—Standard Grade Douglas fir or southern pine.

For details, see the Tentative Specifications for Structural Douglas Fir (Serial Designation: D 23 – 20 T), *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 704 (1920), also 1923 Book of A.S.T.M. Tentative Standards, p. 529; Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (Serial Designation: D 10 – 15), 1921 Book of A.S.T.M. Standards, p. 798; and Standard Specifications for Southern Yellow-Pine Timbers to be Creosoted (Serial Designation: D 24 – 20), 1921 Book of A.S.T.M. Standards, p. 801.

This report is presented as information in order to bring out discussion of the general scheme of classification of grades and types of structures as outlined. No definite naming or description of timber and lumber grades is recommended at this time.

Respectfully submitted on behalf of the sub-committee,

C. E. PAUL,
Chairman.

REPORT OF SUB-COMMITTEE VI ON TIMBER PRESERVATIVES

The sub-committee recommends for acceptance as tentative the proposed Tentative Methods of Chemical Analysis of Zinc Chloride appended hereto,[1] including the following:

1. Preparation and Standardization of Solutions;
2. Determination of Insoluble or Basic Zinc Chloride;
3. Determination of Zinc:
    - (*a*) Volumetric method for use when manganese chloride does not exceed 0.3 per cent;
    - (*b*) Volumetric method for use when manganese chloride equals or exceeds 0.3 per cent;
    - (*c*) Gravimetric method for use as alternate;
4. Estimation of Iron and Aluminum.

All of the proposed methods have been adopted as standards by the American Wood Preservers' Association as the result of a number of years of careful study and cooperative laboratory work conducted by the Committee on Preservatives of that association. Comparative tests made in the laboratories of the largest producers and users of zinc chloride for wood preservation have fully justified the claims for accuracy set forth by that committee. Sub-Committee VI has carefully revised the wording and made certain refinements in the procedure which have been approved by the authors of the methods. The sub-committee, therefore, endorses these methods as seasoned and well-tried, and suitable for acceptance as tentative standards.

In its report for 1923, Committee D-7, on recommendation of Sub-Committee VI, withdrew from the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 18)[2] the sub-division designated Float Test of Residue comprising Sections 17 and 18. It further recommended that the revision of this method by Committee D-4 on Road and Paving Materials published as Tentative Methods D 139 – 23 T be approved as a method of testing creosote oil. During the past year some further refinements have been made in this method, in which Committee D-7, Committee D-4, and the Preservative Committee of the A.W.P.A. have cooperated. The recommendations of Committee D-4 for revision of Methods D 139 – 23 T is concurred in by Sub-Committee VI. Instead of recommending the withdrawal of the entire Sections 17 and 18 of Methods D 38 – 18, however, it recommends that these sections be replaced by the following:

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[1] See p. 995.—Ed.

[2] 1921 Book of A.S.T.M. Standards.

> "The residue remaining in the retort after the distillation test shall remain until it reaches a temperature between 100 and 125° C. The consistency of the residue shall then be determined in accordance with the Tentative Method of Float Test for Bituminous Materials (Serial Designation: D 139 – 23 T) of the American Society for Testing Materials.[1]
>
> "NOTE.—Care must be taken at the end of the distillation test to see that the vapor temperature as indicated on the thermometer, does not rise above 355° C.; an excess temperature of only 1 or 2° C. at this point makes the float test invalid."

Committee D-15 on Thermometers has presented a revised specification for high-distillation thermometers, which differs only in minor dimensional details from that specified by the committee in Section 9 of the Standard Methods D 38 – 18. These specifications are appended to the report of Committee D-15.[2] Sub-Committee VI recommends in the interest of uniformity the withdrawal from the Standard Methods of the present thermometer requirements and that the thermometer specifications recommended by Committee D-15 be substituted with the following note:

> "NOTE.—Inasmuch as those dimensions in the specifications referred to which differ from the corresponding dimensions which appeared in Methods D 38 until their revision in 1924 are of such a nature as to affect the facility of making but not the accuracy of the thermometer, any thermometer now in use complying with the former requirements of D 38 shall be accepted as satisfactory by producers and users of creosote oil; provided that all thermometers hereafter purchased shall be in accordance with the new specifications."

Sub-Committee VI recommends that the revised method of testing for coke residue of creosote oil, accepted last year as a tentative standard, be continued as such. No criticisms of this method have been heard, but the method has perhaps not been in general use for sufficient length of time to warrant adoption as standard.

During the past year Sub-Committee VI, in consultations with the chairman of the Sub-Committee on Volatility of Committee E-1 on Methods of Testing and with members of Committees D-4 and D-2 on Petroleum Products and Lubricants, has brought considerable attention to the question of a suitable distilling vessel for high boiling materials, such as creosote oil, road tars, gas oil and the like.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 756 (1923).

[2] See p. 693.—ED.

Recent developments have been encouraging, and it is hoped that a flask now under observation by interested members of the several committees may prove satisfactory to all. A definite report on this subject may be expected in 1925.

Sub-Committee VI wishes to direct attention to a number of methods of analysis for sodium fluoride that have been adopted by the American Wood Preservers' Association[1] and undoubtedly represent the best available methods for testing sodium fluoride for use in wood preservation. The sub-committee does not believe that there is sufficient demand for these methods nor that the methods have been used widely enough to warrant recommending them as tentative standard at the present time.

The Sub-Committee on Water in Bituminous Materials of Committee E-1 on Methods of Testing requests that approval be given to the Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T) for water determination only. This method has already been adopted by Committees D-2 on Petroleum Products and Lubricants and D-4 on Road and Paving Materials. It is recommended that this method be approved as an alternate to the method contained in Methods D 38 – 18 where water determination is the sole purpose, thus providing a choice of two methods.

Respectfully submitted on behalf of the sub-committee,

S. R. CHURCH,
Chairman.

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[1] *Proceedings*, Am. Wood Preservers' Assoc., 1923, p. 73.

REPORT OF SUB-COMMITTEE IX ON METHODS OF TESTING

During the year, Sub-Committee IX contributed to the work on the standardization of methods of test through representation by all its members on the Sectional Committee on Methods of Testnig Wood of the American Engineering Standards Committee now working along this line. As a culmination of this work with the Sectional Committee, a procedure entitled "Proposed Tentative Methods for Conducting Static Tests of Timber in Structural Sizes" was prepared. It was the thought in this development to cover in a very definite way the procedure for tests of certain types of timber, such as bridge stringers and joists, and at the same time present as far as possible desirable practice in connection with other structural timber forms. The underlying objective is the establishment of practice which will give data comparable to those already available on certain species, to the end that all results obtained at various sources may be of the greatest ultimate value. The field of testing is obviously so broad that the standards proposed should not tend to remove initiative and prevent progress, for where certain special factors are to be investigated it will, of course, still be necessary to develop special test methods or modify practice to meet the objective in view. It is hoped, however, that the principles incorporated in the proposed methods will serve as a guide in tests of even a special nature.

The proposed Tentative Methods for Conducting Static Tests of Timbers in Structural Sizes and the Tentative Methods of Testing Small Clear Specimens of Timber (D 143 - 22 T) were both submitted by the A.E.S.C. Sectional Committee to its members and to some sixty universities and laboratories for comment and criticism.

At a meeting of the Sectional Committee held in Madison on April 14 to consider these test procedures and the comments received, Sub-Committee IX was represented by Messrs. Withey and Markwardt. The unpublished revisions of Methods D 143 - 22 T adopted by Committee D-7 on January 16, 1923, were accepted by the Sectional Committee, a preface was adopted, and certain other revisions made. Sub-Committee IX concurs in the action taken, and recommends that, as revised, the A.S.T.M. Tentative Methods of Testing Small Clear Specimens of Timber (D 143 - 22 T) be continued as tentative. The proposed revisions are appended.

A preface as well as some other modifications to the preliminary draft of proposed Tentative Methods for Conducting Static Tests of

Timbers in Structural Sizes was adopted by the A.E.S.C. Sectional Committee. Sub-Committee IX concurs in this action also, and recommends the publication of this procedure as an A.S.T.M. tentative standard. The methods are appended.[1]

Respectfully submitted on behalf of the sub-committee,

L. J. MARKWARDT,
Chairman.

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[1] See p. 976.—ED.

APPENDIX

PROPOSED REVISIONS OF TENTATIVE METHODS OF TESTING SMALL CLEAR SPECIMENS OF TIMBER (D 143 – 22 T)[1]

1. Add the following "Preface":

"The everyday use of timber for multitudinous purposes makes manifest a continual need of data on its mechanical properties. The great variety of species, the variability of the material, the continually changing conditions of supply, the many factors affecting test results, all combine to make the technique of testing wood unique in its complexity.

"In the preparation of this procedure for testing small clear specimens, consideration was given both to the desirability of adopting methods which would yield results comparable to those already available and to the possibility of embodying such improvements as experience has shown desirable. In view of the many thousands of tests made under a single comprehensive plan by the U. S. Forest Service, the Forestry Branch of the Department of the Interior, Canada, and other similar organizations, the procedure naturally conforms closely to the methods used by these institutions. This procedure is the outgrowth of a study of both American and European experience and methods. Its general adoption will tend toward a world-wide unification of results, permitting an interchange and correlation of data, and will establish the basis for a cumulative body of fundamental information on the timber species of the world.

"The methods under consideration represent the entire procedure from selection of the trees to the manipulation of the test, thus controlling factors, such as the size and proportion of test specimens and rate of loading, which may influence results. No attempt has been made to cover methods of computation and analysis, as these questions may be considered independently at any time. Such sample data and computation sheets and cards have been incorporated, however, as were thought to be of assistance to the investigator in systematizing records."

2. *Section 1 (b)*.—Change to read as follows:

"Data for the establishment of correct strength functions which, in conjunction with results of tests of timbers in structural sizes,[2] afford the basis for fixing allowable stresses."

3. *Section 2*.—Change to read as follows:

"The principal mechanical tests are static bending, compression parallel to grain, impact bending, compression perpendicular to grain, hardness, shear parallel to grain,[1] tension perpendicular to grain, cleavage, and tension parallel to grain. These tests are made on both green and air-dry material as hereinafter specified. In addition, such physical properties as specific gravity, radial shrinkage, tangential shrinkage, and shrinkage in volume are determined."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 827 (1922).

[2] See Tentative Methods for Conducting Static Tests of Timbers in Structural Sizes, p. 976.

4. *Section 5 (a).*—Change the footnote to read as follows:

"This tree is intended to furnish test material for studying, among other things, the variation of properties with height in trees and provides for this purpose a 4-ft. section from different heights. Experience has shown that four sections or bolts, each 4 ft. in length, will usually be sufficient for studying the influence of height in tree on the mechanical properties."

5. *Section 19.*—Add the following footnote reference to the word "bolts," line 5:

The 8-ft. section (*c* and *d* bolts) from each of the two trees provided for under Section 5 (*b*) is intended for tests to determine the effect of air drying on strength.

6. *Figure 5.*—Change so that the direction of the rings as shown on the end of the specimen will be horizontal, to conform to Section 45.

7. *Figure 8.*—Change end view to a cross-section of center of specimen, and omit the cross-hatched section now shown.

8. Add a new Section 79 after Section 78, as follows, and renumber the remaining sections:

"79. *Rate of Application of Load.*—The load shall be applied continuously throughout the test at a rate of 0.25 in. per minute."

9. *Section 114.*—Add the following footnote:

"The A.S.T.M. has adopted Tentative Methods of Verification of Testing Machines (E 4 - 23 T).—See *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 911 (1923)."

10. *Appendix, Figure 8.*—Change "Load at 0.1 in. Defl. = 4000 lb." to read "Load at 0.092 in. Compression = 4000 lb."

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[1] The test for shearing strength perpendicular to the grain (sometimes termed "vertical shear") is not included as one of the principal mechanical tests since in such a test the strength is limited by the shearing resistance parallel to the grain.

REPORT OF COMMITTEE D-8

ON

WATERPROOFING MATERIALS

Committee D-8 has held three meetings during the past year. Its Sub-Committee on Service Tests has been discharged for reasons given in its final report, appended hereto.

Owing to the very close relationship between bituminous waterproofing and roofing materials, the tests to which they are subjected and their methods of use, the committee has requested that its title be changed to "Committee D-8 on Bituminous Waterproofing and Roofing Materials." There appears to be a growing demand for standard tests and specifications for roofing materials and Committee D-8 feels that more rapid progress will be made by placing the subject within the scope of its own work than by creating a new standing committee on roofing products.

Committee D-8 is in accord with the recommendations on definitions for "specific gravity" as covered in the annual report of Committee D-4 on Road and Paving Materials and has so advised Committee E-8 on Nomenclature and Definitions. These recommendations were submitted to letter ballot of Committee D-8 and the following returns received:

Item	Affirmative	Negative	Not Voting
1. Recommendation that term "specific gravity" be used in preference to the term "density" for ordinary technical work	25	0	9
2. Definition for Absolute Specific Gravity	25	0	9
3. Definition for Specific Gravity	25	0	9
4. Definition for Apparent Specific Gravity	25	0	9
5 Definition for Relative Specific Gravity	25	0	9
6. Definition for Relative Apparent Specific Gravity	25	0	9

PROPOSED REVISIONS OF TENTATIVE SPECIFICATIONS AND METHODS OF TEST

1. *Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 - 23 T).*[1]—The following revisions are recommended in these methods:

Section 1.—Change the definitions to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 805 (1923)

"*Bituminous Grout.*—A mixture of bituminous material as a binder and sandy mineral matter as an aggregate, which [at approximately 300° F.] *between 149° C. (300° F.) and 205° C. (400° F.)* becomes sufficiently fluid to flow into place without mechanical manipulation, and which on cooling congeals to a compact mass.

"*Asphalt Mastic.*—(1) A mixture containing asphaltic material as a binder and graded mineral matter as an aggregate, or (2) pulverized [natural bituminous rock] *native rock asphalt* (to which [bitumen may be added] *asphaltic material may have been added*); either of which at approximately *205° C. (400° F.)* may be poured into place but which requires [trowelling] *a trowel* to form it into a compact mass.

"*Asphalt Mastic Cake.*—A mixture containing asphaltic material as a binder and an aggregate consisting *chiefly* of calcareous or siliceous dust [, together with sand] cast [in] *into* the form of blocks or 'cakes' and adapted for use in preparing asphalt mastic."

It is recommended that the methods as revised, be continued as tentative.

2. *Tentative Specifications for Asphalt Mastic for Use in Waterproofing (D 169 – 23 T)*.[1]—The following revision is recommended in these specifications:

Section 2.—Insert the word "This" at the beginning of the first sentence which will then read:

"This asphalt mastic is a mixture of mastic cake, asphalt cement and mineral aggregate, which at a temperature of approximately 205° C. (400° F.) is sufficiently plastic to be poured into place and compressed with a wooden trowel or equivalent tool into a compact mass."

It is recommended that the specifications as revised be continued as tentative.

3. *Tentative Specifications for Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 – 23 T)*.[2]—The following revisions are recommended in these specifications:

Section 2.—Insert the word "This" at the beginning of the first sentence which will then read:

"This bituminous grout is a mixture of substantially 45 parts by weight of bituminous binder and 55 parts by weight of mineral aggregate as coarse as sand, which becomes sufficiently fluid when heated to approximately 400° F. (205° C.) to flow without mechanical manipulation, and which on cooling congeals to a compact mass."

Section 3 (b).—If the new proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level submitted with this report are accepted: it is recommended that this paragraph be changed to read as follows,

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 781 (1923).

[2] *Ibid.*, p. 783.

> "(*b*) The coal-tar pitch shall conform to either of the following tentative specifications of the American Society for Testing Materials:
>
> "(1) Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 42 - 24 T);
>
> "(2) Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D - 24 T)."

It is recommended that the specifications as revised be continued as tentative.

4. *Tentative Specifications for Bituminous Grout for Use in Waterproofing Below Ground Level* (*D 171 - 23 T*).[1]—The following revisions are recommended in these specifications:

Section 2.—Insert the word "This" at the beginning of the first sentence which will then read:

> "This bituminous grout is a mixture of substantially 45 parts by weight of bituminous binder and 55 parts by weight of mineral aggregate as coarse as sand which becomes sufficiently fluid when heated to approximately 300° F. (149° C.) to flow without mechanical manipulation, and which on cooling congeals to a compact mass."

Section 3 (*b*).—If the new proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level submitted with this report are accepted, it is recommended that this paragraph be changed to read as follows:

> "(*b*) The coal-tar pitch shall conform to either of the following tentative specifications of the American Society for Testing Materials:
>
> "(1) Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 42 - 24 T).
>
> "(2) Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D— - 24 T)."

It is recommended that the specifications as revised be continued as tentative.

5. *Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level* (*D 40 - 23 T*).[2]—The following revision is recommended in these specifications:

Section 1.—Change the first sentence to read as follows by the addition of the italicized words:

> "These specifications cover asphalt suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 785 (1923).

[2] *Ibid.*, p. 773.

of waterproofing below ground level, under uniformly moderate temperature conditions *both during the process of installation and during service.*"

Section 4.—Change Paragraph (*g*) to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

"(g) Insoluble in carbon disulfide..........not more than [1] *5* per cent."

It is recommended that the specifications as revised be continued as tentative.

6. *Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level (D 144 - 23 T).*[1]—The following revisions are recommended in these specifications:

Section 1.—Change the first sentence to read as follows by the addition of the italicized figures and the omission of those in brackets:

"These specifications cover asphalt suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing above ground level, where not exposed to a temperature exceeding [100° F. (37° C.)] *115° F. (46.1° C.).*"

Section 2.—Omit the word "embankments" in the third line.

Section 4.—Change Paragraph (*a*) to read as follows by the addition of the italicized figures and the omission of those in brackets:

"(a) Softening point by the Ring-and-ball method................[150 to 200° F. (65.5 to 93.3° C.)] *150 to 170° F. (65.5 to 76.7° C.).*"

At the beginning of Paragraph (*b*) insert the following requirement:

"Penetration at 46.1° C. (115° F.), 50 g., 5 sec.......not more than 100."

Change Paragraph (*f*) to read as follows by the addition of the italicized figure and the omission of those in brackets:

"(f) Ductility at 25° C. (77° F.)..........not less than [3] *15* cm."

It is recommended that the specifications as revised be continued as tentative.

7. *Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (D 42 - 23 T).*[2]—The following revisions are recommended in these specifications:

Section 1.—Change to read as follows by the addition of the italicized words:

"These specifications cover high-carbon coal-tar pitch suitable for use as a mopping-coat in damp-proofing or as a plying-cement in the construction of a membrane system of waterproofing below ground level, under uniformly moderate temperature conditions *both during the process of installation and during service*."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 775 (1923).

[2] *Ibid.*, p. 777.

Section 4 (e).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"(e) Specific gravity at [25°/25° C. (77°/77° F.)] *38°/25° C. (100°/77° F.)* of total distillate to 300° C. (572° F.).........not less than 1.03."

It is recommended that the specifications as revised be continued as tentative.

8. *Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level (D 145 – 23 T)*.[1]—The following revisions are recommended in these specifications:

Section 1.—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"These specifications cover high-carbon coal-tar pitch suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing above ground level, when not exposed to a temperature exceeding [100° F. (37.7° C.)] *115° F. (46.1° C.)*."

Section 2.—Omit the word "embankments" in the third line.

Section 4.—Change Paragraph (*e*) to read as follows by the addition of the italicized figures and the omission of those in brackets:

"(e) Specific gravity at [25°/25° C. (77°/77° F.)] *38°/25° C. (100°/77° F.)* of total distillate to 300° C. (572° F.).........not less than 1.03."

Change Paragraph (*f*) to read as follows by the addition of the italicized figures and the omission of those in brackets:

"Ductility at 25° C. (77° F.).........not less than [15] *20* cm."

It is recommended that the specifications as revised be continued as tentative.

NEW SPECIFICATIONS SUBMITTED AS TENTATIVE

The committee recommends for publication as tentative the following specifications appended hereto[2] as prepared by the Sub-Committee on Membrane Materials:

(*a*) Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level;

(*b*) Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 779 (1923.)

[2] See pp. 1007–1010.—ED.

ENDORSEMENT OF RECOMMENDATION OF COMMITTEE D-2

Committee D-8 endorses the recommendation contained in the annual report of Committee D-2 on Petroleum Products and Lubricants that the Tentative Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T), as amended, be advanced to standard.

The results of the letter ballot of the committee upon the recommendations made in this report are as follows:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF EXISTING TENTATIVE STANDARDS			
Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 – 23 T)	21	0	13
Tentative Specifications for Asphalt Mastic for Use in Waterproofing (D 169 – 23 T)	21	0	13
Tentative Specifications for Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 – 23 T)	21	0	13
Tentative Specifications for Bituminous Grout for Use in Waterproofing Below Ground Level (D 171 – 23 T)	21	0	13
Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level (D 40 – 23 T)	22	0	12
Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level (D 144 – 23 T)	22	0	12
Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (D 42 – 23 T)	16	2	16
Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level (D 145 – 23 T)	16	2	16
II. PROPOSED NEW TENTATIVE STANDARDS			
Proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level	15	3	16
Proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level	15	3	16

This report has been submitted to letter ballot of the committee, which consists of 34 members, of whom 22 have voted affirmatively, none negatively, and 12 have refrained from voting.

Respectfully submitted on behalf of the committee,

PRÉVOST HUBBARD,
Secretary.

S. T. WAGNER,
Chairman.

EDITORIAL NOTE

The proposed revisions of the Tentative Specifications for Asphalt Mastic, for Bituminous Grout for Use in Waterproofing, for Asphalt for Use in Damp-proofing and Waterproofing and for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing and of the Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures were approved at the annual meeting, as recommended in this report. The tentative standards, as thus revised, appear on pages 999–1000 and 1011–1022.

The two proposed Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing, referred to in this report, were accepted for publication as tentative and appear on pages 1007–1010.

FINAL REPORT OF SUB-COMMITTEE ON SERVICE TESTS OF WATERPROOFING MATERIALS IN GENERAL

For approximately two years, the sub-committee, has attempted to obtain data in regard to results secured with various waterproofing materials which had been in service. Such data was difficult to obtain, and only a comparatively small amount was received. It is felt that unless a vast quantity of such information is accumulated, together with data covering the design of the structures which were waterproofed, method of application and conditions under which the waterproofing was placed, it is doubtful whether any conclusions in regard to the service of waterproofing materials themselves can be drawn. It was therefore the opinion of practically all of the members of this sub-committee that, with such information as was available, it would be impossible to draw conclusions dealing solely with waterproofing materials.

The atmospheric and temperature conditions under which waterproofing materials are used vary widely; the waterproofing may be exposed to the air, it may be protected by a covering of mastic, brick, concrete or timber, or it may be thoroughly protected, as in the case of tunnels, subways and foundations.

Further, all structures waterproofed may be divided into two general classes: one in which vibration is present, the other in which there is no vibration. It was also agreed that, in any structure which is successfully waterproofed, the matter of design of structure, workmanship in the application of materials and the characteristics of waterproofing materials themselves are three factors of prime importance, very closely associated, and it is difficult if not impossible to separate one from the other.

It further seems that, with proper design and workmanship, there has been wide variation in results obtained, so that the opinion in general was expressed that, these two factors being satisfactory, various waterproofing materials would give satisfactory service.

In this connection it should be remembered that the American Society for Testing Materials devotes its activities exclusively to materials, and, therefore, the sub-committee does not feel that it can enter into a discussion or make recommendations bearing on either design of structures or workmanship.

The sub-committee does not feel that its action in requesting discharge, for the reasons stated, has any material bearing on the general activities of Committee D-8 in bringing out specifications for waterproofing materials. While it might be possible for the sub-committee to bring out rather general statements of the desirable qualities to be obtained in waterproofing materials, this would simply be a summary of the various qualities definitely specified in the separate materials specifications recommended by Committee D-8.

This report has been referred to letter ballot of the sub-committee. Of a total of 14 members, 12 voted for the adoption of the above recommendations, one for their rejection, and one did not vote.

Respectfully submitted on behalf of the sub-committee,

P. G. LANG, JR.,
Chairman.

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS

Committee D-9 has held three meetings during the year, in addition to the one to be held during the annual meeting of the Society, as follows:

At Pittsburgh, December 5 and 6, 1923;
At New York City, January 15, 1924;
At Washington, D. C., March 20 and 21, 1924.

The activities of the committee have been continued in the development and standardization of methods of testing electrical insulating materials. In addition to further study of the existing standards and tentative standards under the jurisdiction of the committee, in the light of the experience gained with their use, much work has been done on the formulation of additional methods and in investigating various phases of the general subject of insulations.

The rapid expansion of the electricity supply industry in this country has required the employment of higher and higher voltages for the transmission of power with the result that insulation problems have become more prominent each year. Furthermore, the great rate of increase in the size of generating and distribution systems, which is now taking place, means the concentration of large blocks of power at points of failure with consequent greater destruction and disturbance of the service, thus making the reliability of insulations more and more necessary. The committee notes with much satisfaction the marked increase during the past year in the amount of intensive study which is being given to the fundamentals of electrical insulations by several of the large interests in the industry. For despite the tremendous growth and present size of the electrical industry, the basic mechanism of breakdown of insulations under electrical stress and the laws which govern their performance are just beginning to be understood. Much research work is now being done, however, in the laboratories of universities and manufacturing concerns so that our knowledge of these fundamentals is increasing rapidly. Increase in fundamental knowledge will obviously facilitate the development of methods of making effective commercial tests and the formulation of better materials specifications.

EXISTING STANDARDS AND TENTATIVE STANDARDS

Standard Methods of Testing Molded Insulating Materials (D 48-22).[1]—In the practical use of these methods the deformation point in the test for distortion under heat is obtained by direct observation and the deformation curve is rarely used. The following deletion is therefore recommended:

Section 21 (e).—Omit this paragraph reading as follows:

> "A curve for each test specimen showing the time in minutes horizontally and the amount of deflection and also the temperature at given intervals, as vertical ordinates is shown in Fig. 6".

This omission carries with it the omission of Fig. 6.

As this is a deletion of a minor requirement,it is requested that the rule regarding publication as tentative of a revision of an existing standard be waived and that the methods be revised by action of the annual meeting of the Society.

It is recommended that the following minor changes be made:

Sub-heading IV, Dielectric Strength.—Change this title to read, "Dielectric Strength at Commercial Power Frequencies."

It is requested that in this case also the rule regarding publication as a tentative revision of an existing standard be waived.

A revision of the second paragraph in Sections 4(*a*) and 8(*a*) with a view to making the test more precise as to temperature is under consideration but is not yet ready for submission to the Society.

Preliminary drafts of methods of testing these materials for volume resistivity and surface insulation resistance have been considered by the committee but they are not yet formulated in final shape.

A preliminary design for an impact testing machine suitable for molded insulating materials has been made and some machines are under construction. An impact fatigue test is also being investigated and it is hoped that both of these tests together with the two insulation resistance tests will be ready for submission next year.

A criticism has been made of the specimen prescribed for the water-absorption test, but the committee is not yet prepared to recommend a change.

The standardization of a test for carbonization produced by an electric arc has been suggested several times but the committee does not see how the difficulties involved in standardizing a method of making the test and measuring the result can be readily overcome.

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[1] A.S.T.M. Standards Adopted in 1922.

Tentative Methods of Testing Insulating Varnishes (*D 115 – 23 T*).[1]—The committee recommends that these methods be revised as follows:

Section 6.—In Paragraph (*a*), insert the word "dust" before the words "free air."

In Paragraph (*b*), change the temperature of drying as given in the second sentence from 100° C. (212° F.) to the range 105 to 110° C. (221 to 230° F.). In the same sentence, insert the word "dust" before the words "free air."

Section 9 (*a*).—Change the diameter of electrodes as specified in the first sentence from 3 cm. (1.18 in.) to 5.08 cm. (2.0 in.) and the rate of application of the potential as given in the second sentence from "such that puncture will occur in 10 to 15 seconds" to "0.5 kv. per second."

With this change the diameter of electrode and rate of application of the potential will conform to that specified for sheet materials in the TentativeMethod of Test for Dielectric Strength of Sheet and Tape Insulating Materials Under Momentary Dielectric Stress (D 149–23 T).

Change the note at the end of this paragraph to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "NOTE.—When necessary in order to get 10 punctures [an addition specimen] *additional specimens* should be tested."

Section 20.—Change the second sentence to read as follows by the addition of the italicized words:

> "The paper shall be withdrawn at a slow and uniform rate (*about 38 cm.* (*15 in.*) *per minute*)."

It is recommended that these methods, with the above changes, be continued as tentative.

A criticism has been made that kraft paper is a better base material than sheet copper or brass as now prescribed for dielectric strength tests, the assertion being made that greater uniformity of test results is obtained. As the data submitted with the criticism were very striking, a series of comparative tests by six different laboratories has been arranged. Specimens of a large sample of each of two kinds of varnish together with a supply of kraft paper from the same roll were furnished to each of these laboratories with instructions to make and test specimens of each varnish prepared (*a*) as prescribed in Methods of Testing D 115 – 23 T with sheet copper, (*b*) with the kraft paper supplied with the samples instead of copper, and (*c*) with kraft paper which each laboratory would have used if kraft paper were prescribed in the standard method. The results of these tests are not yet available.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 811 (1923).

A suggestion has been received that a dielectric strength test of varnish in the liquid state is of as much value as that of the dried films. This is being investigated.

Tentative Methods of Testing Electrical Porcelain (*D 116 - 21 T*).[1]—An automatic form of weight-dropping type of impact machine, where the distance is increased after each blow, has been found more convenient and satisfactory than the simple hand-operated apparatus shown in Fig. 8. It is therefore recommended that Sections 12 to 15, inclusive, be changed from their present form: namely,

"12. The test shall be made with the apparatus shown in Fig. 8.

"13. The test specimen shown in Fig. 7 shall be used for impact tests.

"14. (*a*) The specimen shall be placed on the base of the device directly under the hammer with a disk of blotting paper on the top of the specimen. The collars shall be set for a 6-in. drop of the hammer. The hammer shall be raised to the stops and allowed to fall unimpeded upon the specimen. A fresh disk of blotting paper shall be used for each blow of the hammer.

"(*b*) The entire hammer shall weigh 1.87 lb. (850 g.).

"(*c*) If the specimen remains unbroken after 20 blows of the hammer using the 6-in. drop, the drop shall be increased to 7 in. and the test repeated. If the specimen remains unbroken after 20 blows using the 7-in. drop, the distance shall be increased to 8 in. and the test repeated. If necessary, increasing the height 1 in. per 20 blows shall be continued until the specimen breaks.

"(*d*) Not less than five specimens shall be tested in the condition in which they are received.

"15. The report shall include a statement of the number of blows required to break each specimen with a 6-in. fall of the hammer or, if failure did not occur with the 6-in. drop, the total number of blows and heights of drop necessary to fracture each specimen."

to read as follows:

"12. *Apparatus.*—The test shall be made with an apparatus in which a weight of 1 lb. is raised ½ in. and allowed to fall on the specimen. It is then raised 1 in. and allowed to fall again on the specimen. This is continued, the weight being raised and dropped through a distance increasing by increments of ½ in. until the specimen is broken.

"13. *Specimen.*—The test specimen shown in Fig. 7 shall be used for impact tests.

"14. (*a*) *Procedure.*—The test specimen shall be clamped in the base of the impact tester directly under the hammer. The stops shall be set to give a successively increasing rise of hammer by ½-in. increments, the first height being ½ in.

"(*b*) The entire hammer shall weigh 1 lb.

"(*c*) The test shall be continued until the specimen cracks.

"(*d*) Not less than five specimens shall be tested in the condition in which they are received.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 777 (1921).

"15. *Report.*—The report shall include the numbers of blows required to break each specimen, the energy of each blow in inch-pounds and the total energy in inch-pounds (that is, the sum of all blows).

"NOTE.—The apparatus may be a simple hand-operated one constructed along the line of the one shown in Fig. 8 or a motor-operated machine where the weight is lifted and the distances are increased automatically."

Tentative Methods of Testing Transformer and Switch Oils (D 117 - 21 T).[1]—These methods have been published as tentative for three years and no serious criticism has been received. It is therefore recommended that they be advanced to standard.

Tentative Methods of Test for Dielectric Strength of Sheet and Tape Insulating Materials Under Momentary Dielectric Stress (D 149 - 23 T).[2]—Dielectric strength tests are naturally among the most important of the tests made on electrical insulating materials. They have been the subject of much study and discusion by the committee, particularly as applied to sheet materials, which form such a large part of the insulation used on electrical apparatus.

It has long been appreciated that time has a marked influence on dielectric strength. That is, the longer the time of application of the voltage, the lower the apparent dielectric strength. Obviously the maximum voltage which a given material will withstand indefinitely is of more value than that obtained under the application of voltage for only a few seconds. But the former requires too long a time for general use and the shorter-time test is quite sufficient for many purposes, such as control tests, acceptance tests, quick comparisons, etc. On the other hand, a test which involves some of the time element is often desirable even in routine tests. The committee therefore proposes three arbitrarily standardized dielectric strength tests, namely, (*a*) short-time dielectric strength test, (*b*) one-minute step-by-step dielectric strength test, and (*c*) endurance dielectric strength test.

The report of the committee for 1923 contained curves which showed the marked effect of the rate of application of voltage in short-time dielectric strength tests.[3] The conclusions indicated at that time have been confirmed by further extensive tests by Mr. C. L. Kasson using a specially built apparatus in which the rate of application could be automatically controlled at any value. It is clear that for standardization purposes the rate prescribed in the existing procedure should be decreased.

The committee therefore recommends that the existing tentative standard be replaced by the one appended hereto.[4]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 737 (1921).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 817 (1923).

[3] *Ibid.*, pp. 441–442.

[4] See p. 1039.—ED.

A report was made to the committee that the majority of punctures with the standard 2-in. electrodes occurred at or beyond the edge of the electrodes but that if the corners of the electrodes were left square, instead of being rounded as prescribed, practically all of the punctures occurred within the edge. An investigation of this point was made by one of the laboratories represented on the committee. A series of tests was made on a sample of yellow varnished cloth, 12 to 13.5 mils thick, and also on a sample of black varnished cloth, 12.5 mils thick, using (*a*) 2-in. flat disk electrodes having standard round corners as prescribed and (*b*) similar electrodes with square corners. Twenty punctures were made on each cloth with each kind of electrode with the following results:

	YELLOW CAMBRIC		BLACK CAMBRIC	
	WITH ROUNDED CORNERS	WITH SQUARE CORNERS	WITH ROUNDED CORNERS	WITH SQUARE CORNERS
Maximum Kilovolts at Puncture	17.5	16.0	17.5	17.5
Minimum Kilovolts at Puncture	10.9	12.0	12.7	13.1
Grand Average Kilovolts at Puncture	15.0	14.9	15.9	15.8
Inside of Edge:				
Number of Punctures	7	7	12	11
Average Kilovolts at Puncture	14.2	15.0	16.1	16.1
At Edge and Outside:				
Number of Punctures	13	13	8	9
Average Kilovolts at Puncture	15.0	14.8	15.4	15.5

These results show that (*a*) the number of punctures within the area of contact was about the same for both rounded and square corners although the proportion was greater with black cambric, (*b*) the average puncture voltage is practically identical in the two cases, and (*c*) the average of the punctures occurring at the edge and beyond was substantially the same as those occurring inside the edge.

Incidentally, in connection with this investigation a test was made with aniline oil in the space formed at the edges of the electrodes with rounded corners to confirm, or otherwise, the statement made by a foreign investigator[1] that the use of this oil, which has a high dielectric constant, would eliminate corona discharge resulting in more consistent results. Yellow cambric cloth only was used, 20 punctures being made. The results were as follows:

Average kilovolts at puncture	14.7
Maximum kilovolts at puncture	16.0
Minimum kilovolts at puncture	12.7
Number of punctures occurring inside edge	13
Average kilovolts	14.7
Number of punctures occurring at edge and beyond	7
Average kilovolts	14.7

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[1] *Archiv. für Elektrotechnik*, Vol. 12, No. 1, pp. 79–100.

The oil effectually eliminated corona discharge but it is apparent from the above results that this had no influence whatever on the average dielectric strength, although more punctures took place within the contact area than where the oil was not used. It may be that a more pronounced effect would be obtained where much higher voltages are required to puncture the specimen.

Tentative Method of Test for Phase Difference (Power Factor) and Dielectric Constant of Electrical Insulating Materials at Radio Frequencies (D 150 – 23 T) and *Tentative Method of Test of Electrical Insulating Materials for Voltage Effects at Radio Frequencies (D 175 – 23 T).*—It is recommended that these be continued as tentative. While no criticism has been received by the committee, it is felt that probably some improvement in these procedures can be made.

Tentative Methods of Testing Cable Splicing and Pothead Compounds (D 176 – 23 T).[1]—The committee recommends that these methods be continued as tentative with the addition of the following sections covering a test for coefficient of expansion:

"III. COEFFICIENT OF EXPANSION

"10. *Apparatus.*—Calibrated flasks of Pyrex or quartz glass holding approximately 250 cc. to the zero mark, having necks 1 cm. in internal diameter and graduated for 25 cc. in 0.1-cc. divisions, total capacity approximately 275 cc., shall be used.

"NOTE.—If it is necessary to use a small sample, then a Cassia flask holding 100 cc., with neck graduated for 10 cc. in 0.1-cc. divisions, may be used.

"11. The cylindrical oil bath for heating the sample shall be approximately 10 in. (25.4 cm.) in inside diameter and 20 in. (50.8 cm.) in inside depth with a false bottom 1 in. from the bottom and shall have provision for circulating the oil.

"NOTE.—This bath may be made as follows: A shell about 10 in. (25.4 cm.) in inside diameter and 20 in. (50.8 cm.) in inside depth is electrically heated by winding the shell with resistance wire and covering with five layers of asbestos paper. A motor-driven paddle at the bottom will give effective oil circulation.

"12. A lead collar to be hung on the flask during test to prevent the oil currents of the bath from moving the flask.

"13. *Calibration.*—The capacity of the flask at the zero point and several points on the scale shall be determined by filling the flask with distilled water at a known temperature and weighing.

"14. *Procedure.*—The flask shall first be warmed slightly, then partly filled with melted compound and placed in the bath which shall then be brought to the highest temperature of the range over which the test is to extend. The flask shall then be filled to within the last cc. marked on the neck. The bath shall be held at this temperature for not less than 30 minutes (principally to remove air bubbles) and the whole shall then be slowly cooled to room temperature (10 to 12 hours). Before starting the test, the flasks shall be examined for the presence of cavities or irregular contraction of the compound. Some compounds, after cooling below the liquid state, tend to stick to the sides of the neck of the flask. In that case it is necessary to gradually warm the neck and flow the compound to meet the rest, after which the flask is placed in the bath for an hour or so to insure equalizing the temperature.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 848 (1923).

"With the compound satisfactorily placed in the flasks at the lowest temperature, the height of the column in the neck shall be read and the bath then slowly heated. Readings shall be taken at 5° C. intervals, holding the bath as constant as possible at each point until no more expansion occurs at that point, the procedure being repeated for each point until maximum temperature is reached.

"15. *Precautions.*—During the test, temperature readings shall be taken at top and bottom of the bath to detect any variation.

"Until the compound is completely liquefied, intervals between readings should be three to four hours, especially between 35 and 55° C.

"After becoming liquefied, the time necessary for obtaining a reading may be reduced to about 30 minutes.

"16. *Report.*—(*a*) After securing the readings over the temperature range desired, a curve shall be plotted from the temperature and flask readings from which the coefficient of expansion shall be calculated from the formula:

$$\frac{V_1 - V}{(T_1 - T)\,V} + C$$

Where V = original volume;
V_1 = volume at higher temperature;
T = original temperature;
T_1 = higher temperature;
C = constant = coefficient of expansion of glass container.

"(*b*) The coefficient shall be calculated for three ranges as follows:

(1) From the minimum temperature at which the measurement was made to 10° C. below the melting point. This is intended to give the average coefficient for the solid condition.

(2) From 5° C. above the melting point to 100° C. This is intended to give the average coefficient for the liquid condition.

(3) From the minimum temperature at which a measurement was made to 100° C.

"In reporting the coefficient of expansion the corresponding temperature range shall be indicated in each case."

PROPOSED NEW TENTATIVE STANDARDS

Proposed Tentative Methods of Testing Untreated Insulating Paper are appended to this report.[1] It is recommended that they be accepted for publication as a tentative standard.

MISCELLANEOUS

Life Test of Transformer Oils.—The sub-committee dealing with liquid insulations has devoted much study to the subject of sludging of transformer oils for several years and our annual reports have given considerable space to the subject. The committee reaffirms the view previously expressed that none of the various methods which have been used heretofore is entirely satisfactory as a general standard.

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[1] See p. 1051.—ED.

During the past year the sludge test method described in an appendix to the 1923 report of this committee[1] has been under trial. Several laboratories represented on the committee have installed the apparatus, but sufficient experience by others than the one laboratory where it was developed has not yet been had to justify recommending it as a tentative standard at this time. However, the experience so far obtained has been favorable and it seems highly probable that this method will be recommended as a tentative standard next year. A revised description of the method with more details of the construction is given in Appendix I.

A review and discussion of the various sludging test methods with criticisms is given in a paper being presented at this meeting by Mr. E. A. Snyder.[2] A discussion of the new method referred to is also included together with some test results.

Thermal Conductivity.—A simplified form of the electrical method of measuring thermal conductivity of sheet insulating materials, which was under consideration last year and referred to in last year's report,[3] has been proposed as a standard method. This is being investigated but progress has been delayed by other work which is considered more important. It is expected, however, that the new apparatus will be constructed and the method given a trial during the coming year.

Deterioration of Sheet Materials.—The committee had expected to make some progress in the development of a standard method for rate of deterioration in sheet insulating materials but the pressure of other matters has necessitated deferring this until next year. A rather extensive series of tests is contemplated because a considerable amount of data must be obtained before a reliable method of measuring deterioration can be recommended. Methods of deterioration to be investigated include physical tests for tensile strength, bursting strength, tearing strength and folding endurance together with electrical tests for dielectric strength and power factor.

A preliminary report of an extensive investigation of the rate of deterioration of paper insulation as applied to electric power cables, which is being made at the Massachusetts Institute of Technology by Professor Bush under the auspices of a committee of the National Electric Light Association and the Association of Edison Illuminating

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 448 (1923).

[2] E. A. Snyder, "Sludging Tests for Transformer Oils," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924)

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 441 (1923).

Companies, has just been reported at the annual convention of the National Electric Light Association held in May.[1] This report seems to indicate that a standard form of tearing test is a more sensitive and reliable indicator of deterioration than any of the other physical tests. It was very clearly shown that the dielectric strength test is no measure of deterioration. A dielectric loss test as a measure of electrical deterioration offers possibilities but it was not investigated.

Standard Humidity for Physical Tests of Paper.—Investigations made at the U. S. Bureau of Standards show that paper changes its moisture content very rapidly when changed from an atmosphere at one humidity to an atmosphere at another humidity—moisture equilibrium being established in about three minutes. Similar results are shown in a paper by Messrs. Houston, Carson and Kirkwood before the Technical Association of the Paper and Pulp Industry[2] and by an investigation by one of the members of this committee. Furthermore, the paper referred to shows the marked effect on some of the physical properties which will occur in this short period. The following table summarizes the results obtained for manila rope paper, a paper used very extensively for insulating purposes:

TABLE I.—CHANGES IN PHYSICAL PROPERTIES OF MANILA ROPE PAPER CORRESPONDING TO CHANGES OF MOISTURE CONTENT CAUSED BY EXPOSING THE PAPER TO A RELATIVE HUMIDITY OF 35 PER CENT AFTER CONDITIONING AT 65 PER CENT RELATIVE HUMIDITY.

Time of Exposure, minutes	Moisture Content, per cent	Ream Weight, per cent	Contraction, per cent		Tensile Strength, per cent		Elongation, per cent		Folding, per cent		Tearing, per cent	Bursting, per cent
			Machine Grain	Cross Grain	Machine Grain	Cross Grain	Machine Grain	Cross Grain	Machine Grain	Cross Grain	Machine Grain	
0	9.8	...	....	....	..	..	..	..	..	..	..	...
1	8.5	−1.4	−0.05	−0.15	+10	+14	−25	−22	−58	−35	−15	+3
2	7.9	−2.0	−0.07	−0.22	+13	+18	−30	−27	−72	−50	−19	+3.5
3	7.6	−2.1	−0.09	−0.30	+13	+19	−40	−32	−80	−64	−22	+4

The minus sign (−) indicates decrease.
The plus sign (+) indicates increase.

In the research work being carried out at the Massachusetts Institute of Technology on electric power cable insulation referred to above, it was found that a similar effect, but less rapid, occurs with manila rope paper after impregnation with insulating oils. It is therefore evident that all physical tests of paper whether untreated or treated should be made under standard humidity conditions. In the proposed methods for testing paper appended to this report, standard limits of 60 and 65 per cent have been adopted for relative humidity.

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[1] Report of Underground Systems Committee, 1924.

[2] *Technical Association Papers*, Series 6, June, 1923.

As the absolute humidity is the real factor (in other words, the actual moisture in the paper), it is necessary to fix the temperature limits also, and these have been established at 20 and 30° C., respectively.

Plate Materials.—Some data have been collected on methods of testing insulating materials in plate and board form, but the formulation of standard methods has not yet been undertaken. It is probable that considerable experimental work will be necessary before progress can be made.

Dielectric Strength of Insulating Materials.—A discussion of the general subject of dielectric strength and the various procedures employed in the standards which have been prepared by this committee is given in Appendix II.

Power Loss and Power Factor in Insulating Materials.—The committee has not yet considered it advisabe to recommend standardizing any particular method of making tests for power loss and power factor. A brief general discussion of the subject is given in Appendix III.

Acidity in Oils.—An electric titration method for determining acidity in oils developed in one of the laboratories represented on the committee and suggested for use in connection with transformer oils has been referred to Committee D-2 on Petroleum Products and Lubricants for consideration. It appears in Appendix IV.

The following is the result of the letter ballot vote of the committee, consisting of 40 members, on the recommendations made in this report:

Item	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF STANDARD			
Standard Methods of Testing Molded Insulating Materials (D 48 – 22)	25	0	15
II. TENTATIVE STANDARD ADVANCED TO STANDARD			
Tentative Methods of Testing Transformer and Switch Oils (D 117 – 21 T)	29	0	11
III. PROPOSED REVISION OF TENTATIVE STANDARDS			
Tentative Methods of Testing Insulating Varnishes (D 115 – 23 T)	23	0	17
Tentative Method of Test for Dielectric Strength of Sheet and Tape Insulating Materials Under Momentary Dielectric Stress (D 149 – 23 T)	25	0	15
Tentative Methods of Testing Cable Splicing and Pothead Compounds (D 176 – 23 T).	17	0	23
Tentative Methods of Testing Electrical Porcelain (D 116 – 21 T)	20	0	20
IV. PROPOSED NEW TENTATIVE STANDARD			
Proposed Tentative Methods of Testing Untreated Insulating Paper	24	0	16

This report has been submitted to letter ballot of the committee, which consists of 40 members, of whom 30 have voted affirmatively, none negatively, and 10 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. M. FARMER,
Chairman.

H. S. VASSAR,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Methods of Testing Molded Insulating Materials, recommended in this report, were approved at the annual meeting by nine-tenths vote and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Methods of Testing Transformer and Switch Oils were approved at the annual meeting and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Methods of Testing Insulating Varnishes, the Methods of Test for Dielectric Strength of Sheet and Tape Insulating Materials, the Methods of Testing Cable Splicing and Pothead Compounds and the Methods of Testing Electrical Porcelain were approved, as recommended in this report. The methods, as thus revised, appear on pages 1023–1050.

The proposed Tentative Methods of Testing Untreated Insulating Paper, referred to in this report, were accepted for publication and appear on page 1051.

APPENDIX I

LIFE TEST FOR TRANSFORMER OILS

By E. A. Snyder[1]

Note.—This method was described in Appendix I of the 1923 report of the committee.[2] The following is a revision of the previous description. It includes improvements that have been made in the construction of the apparatus as the result of further experience in several laboratories.

APPARATUS

Referring to Fig. 1, *A* is a double-walled oven, the space between the walls being filled with asbestos. The outside of the oven is insulated with $\frac{1}{2}$-in. gray felt. The dimensions of the oven are approximately 20 in. in outside diameter by 12 in. deep. *B* is a removable lid having a small hole, *X*, in the top for inserting the pipette to withdraw specimens of the samples. The lid also has a mica covered peep-hole, *Y*, to determine when the different beakers during the course of rotation in the oven are properly located under the hole, *X*. *C* is a $\frac{1}{2}$-h.p. nominally constant-speed motor attached with a flexible shaft drive to two worm gears, which connects by means of a shaft through the bottom of the oven to a rotating table shown in the working drawings. *E* is a thermostat, the bulb of which is located approximately in the center of the oven. This thermostat, by means of the relay, *F*, serves to turn on and off one of two electrical heating units located in a false bottom in the oven. The amount of current flowing in this heating unit may be set at any suitable figure by means of the rheostat, *G*. A second rheostat, *H*, controls the current in the main heater, which is always flowing when the oven is in operation. *I* is a recording thermometer whose bulb is in the center of the oven. *T* is a low-form gas washing bottle, capacity 250 cc., which is filled three-quarters full with some good grade of transformer oil and serves as a tell-tale bottle to determine the rate of admission of air through the inlet tube, *S*. Air is passed through the oven at an approximate rate of 1.5 cu. ft. per hour, which is about equivalent to four bubbles per second when the internal diameter of the glass tube leading through the gas washing bottle is $\frac{3}{16}$ in. The revolving table inside of the oven is fitted with eight seats, each of which holds a 600-cc. Pyrex beaker, Griffin form, approximately $3\frac{1}{4}$ in. in inside diameter and $4\frac{3}{4}$ in. high.

METHOD OF OPERATION

To start a test, the heating units and motor are turned on and the oven is allowed to attain a temperature of 120° C. While the apparatus is coming up to temperature, the samples may be prepared as follows:

The beakers should be thoroughly washed, using, first, benzol and finishing with a cleaning solution made as usual from potassium bichromate and sulfuric acid. The cleaning solution is thoroughly washed out with water, beakers are dried in an oven and are then ready for use. Samples should be filtered through good quality filter paper. Five hundred cubic centimeters of each oil should be measured out and poured into the beakers. When the oven has come up to the operating temperature of 120° C. the lid is removed, the eight beakers with their oil samples put in place and the lid then replaced. It is good practice to have the beakers and their oil contents preheated to about 100 to 120° C. just before placing them into the oven so as to avoid cooling off the oven too much. The time at which the oil samples are placed in the oven is noted and considered as the beginning of the run. As the oxidation at this low temperature is quite slow, several days at least will usually have elapsed before any sedimentation occurs, even with the poorest grades of oil. Once a day the motor is stopped and the samples are examined by momentarily lifting a specimen of the oil in a 10-cc. pipette which is inserted in the sampling hole, *X*. As soon as any sample is found to be near the sludging condition, 10 cc. of the oil are removed and placed in a graduated centrifuge tube having a tapering end. From this time on, specimens are withdrawn daily from the oils which are suspected of sludging. The specimens, properly labeled with the date and number of the sample, are allowed to stand overnight and are centrifuged at 1800 r.p.m. for twenty minutes. The tubes are then withdrawn and examined. The number of days which elapse before any sludge appears in this specimen is recorded as the time required to produce sludging in the sample from which it was removed. The time interval counted is the time from when the specimen is placed in the oven until it is removed. The time the specimen stands outside of the oven before cen-

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[1] General Electric Co., Pittsfield Works.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 448 (1923).

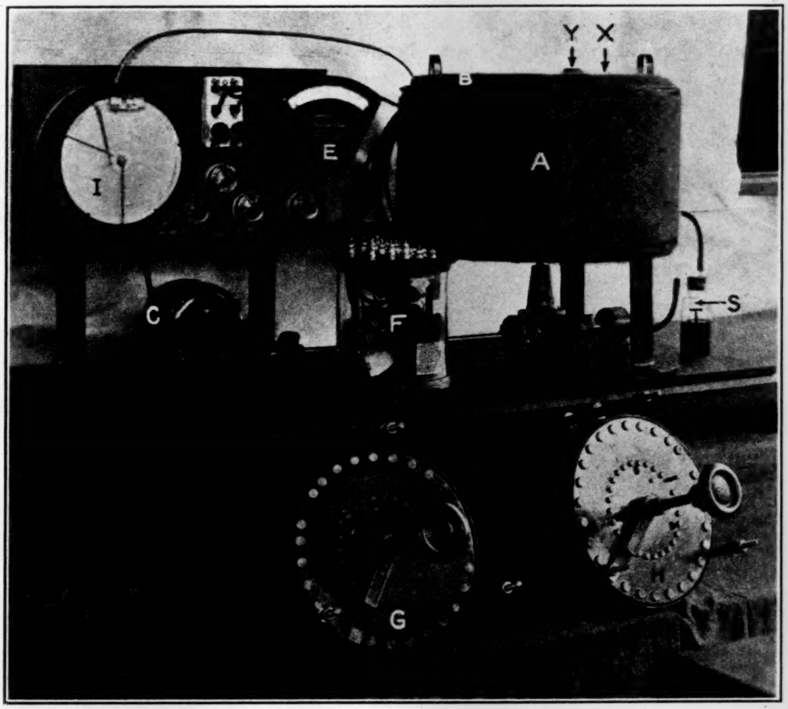

FIG. 1.—Apparatus for Determining Sludging Properties of Transformer Oils.

trifuging is not counted. All specimens must be examined within twenty-four hours after removal from the oven.

NOTES

1. An operator, after some experience with this method, will be able to judge fairly accurately from the darkening of the oil samples when they are approaching the sludging period. When starting with an unknown oil it may be necessary to remove specimens quite early and frequently and then repeat the run without removing specimens, allowing it to proceed closely to the time when sludging first would start. The point to be borne in mind, of course, is that the test will check more accurately with the minimum number of specimens removed before sludging begins. In case the first specimen withdrawn shows sediment, the tests must be repeated and earlier specimens taken.

2. It is very important to maintain the samples at a uniform temperature throughout the run. Best checks will be obtained if the variation is not more than ± 0.5° C. An increase in temperature of 9° C. will double the rate of sludging. If a run underheats or overheats not over 9° C., a correction factor can be applied to obtain the equivalent life at 120° C. This correction factor is most easily obtained by the use of semi-logarithmic paper, as illustrated in Fig. 2. Select a line at about the middle of the paper to represent the normal temperature of 120° C. and let each main division represent 1° C. Locate the point where the 120° C. line intersects the line marked 10, which we will call 1.0, or the uniform rate of sludging. Locate a point where the 129° C. line intersects the line marked 20, which we will call 2.0, or twice the rate of sludging. Draw a straight line intersecting these points. From the intersection of this line with any given temperature line, the factor for correcting an underheated or overheated test run can be applied. For example, suppose the temperature of a run was 123° C. instead of 120° C. Find the intersection of the 123° C. line with the line at *x*. Follow down the dotted line to *y* and read the factor directly as 1.25. Hence, if an oil sludged in 10 days at 123° C., it would require at 120° C., 10 × 1.25 = 12.5 days.

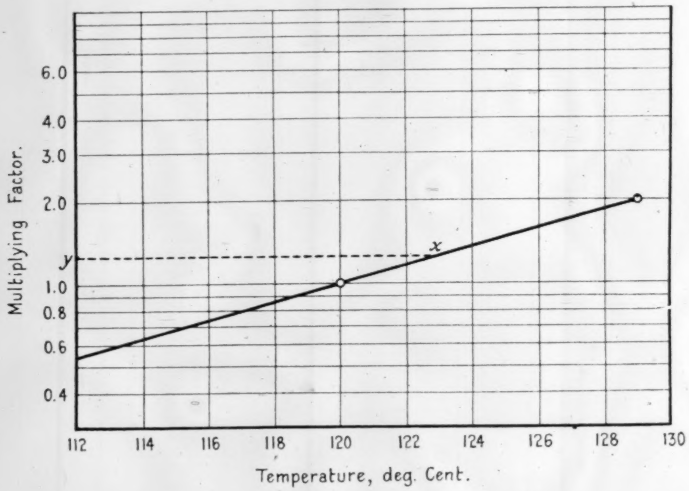

FIG. 2.

3. Sometimes oil specimens after being removed from the oven and allowed to stand in the centrifuge tubes may deposit sludge two or three days after standing. It is important therefore that all specimens be observed within the twenty-four-hour period after removal from the oven. Any results obtained after this twenty-four-hour period should be disregarded. A good plan is to withdraw specimens just before the close of the day and examine them the first thing in the morning. Specimens should not be allowed to stand in direct sunlight, nor should they stand near steam pipes or radiators or in similar locations where they will be kept warmer than the prevailing room temperatures ranging from about 20 to 30° C.

APPENDIX II

DIELECTRIC STRENGTH OF ELECTRICAL INSULATING MATERIALS

The ability of electrical insulating materials to withstand the application of electrical stress is obviously the most important of the several characteristics which are essential in high-voltage applications. The term "Dielectric Strength" is frequently used as a general one referring to this ability to resist breakdown under electrical stress. But in a more restricted sense, it means the highest unit electrical stress which an insulating material can sustain at or just preceding rupture or breakdown. A knowledge of the dielectric strength of insulating materials is therefore obviously essential for the intelligent design and construction of electrical apparatus, and means for its determination must be employed which not only give reliable results but allow of standardization.

The value of the dielectric strength of a material is obtained by measuring the voltage required to break down a specimen of the material when placed between two electrical conductors called "electrodes." It is expressed as the number of volts required to puncture a stated thickness of the material. For comparison purposes it is desirable to express the dielectric strength on a unit basis, that is, the volts per unit of thickness, but this is only strictly correct when the stress gradient is uniform throughout the specimen, that is, when the volts per unit thickness is the same for every unit of thickness. It is usually not possible to determine whether or not the gradient is absolutely uniform, so that the general practice is to assume this to be the case where reasonable precautions are taken to insure it, and it is in that sense that the term is used in this discussion.

The dielectric strength of a given material varies greatly with conditions, such as the form and size of the electrodes, the thickness of the material, the time of application of the potential, the temperature, the surrounding medium, the frequency and wave shape of the voltage, etc. As all of these conditions vary in practice over a wide range, it is not feasible to assign a value for the dielectric strength of a material by means of a laboratory test which will necessarily apply directly to general service conditions. But definite numerical values are required in designing apparatus for comparing materials and for specification purposes. Therefore, it is necessary to standardize the procedure to be followed in obtaining the dielectric strength of insulating materials by arbitrarily fixing the more important conditions which affect the dielectric strength. The purpose of this paper is to discuss some of these conditions and the reasons which led Committee D-9 to adopt the particular details prescribed in various tentative methods of test for dielectric strength which it has prepared and recommended to the Society.

Shape and Size of Electrodes.—Dielectric strength is defined as a voltage gradient, that is, the maximum potential per unit thickness which the material will withstand. The shape and arrangement of electrodes for determining this property must therefore be such that the gradient can readily be determined. The simplest arrangement is of course one where the gradient is uniform throughout the insulation between the two electrodes so that the voltage gradient at rupture is obtained directly from the total voltage applied to the specimen and the thickness of the specimen. It is to be noted, however, that where the voltage gradient throughout the insulation is not uniform, the breakdown voltage is not necessarily a function of the maximum voltage gradient in the material. There is much evidence that in structures where the shape of the two electrodes is such that the gradient varies throughout the insulation (between concentric cylinders, for example, such as lead-sheathed electric cables), the maximum stress gradient when breakdown occurs may be much higher than the dielectric strength of the material as defined above. In other words, a part of the insulation may be stressed very considerably above its dielectric strength as defined above, but breakdown is prevented by the remaining insulation which is not stressed to this limit.

The simplest arrangement for standardized testing purposes is to have the two electrodes similar in shape and size, mounted co-axially and directly opposite each other with the insulation between them. Unfortunately it is not feasible to use the same electrodes for all materials and consequently different shapes and sizes have been adopted as follows:

1. *For Liquid Insulations—Circular Disk Electrode One Inch in Diameter.*—Three forms of electrodes were in more or less general use before Committee D-9 took up this standardization so that practically the choice was confined to ½-in. spheres, ½-in. disks and 1-in. disks. One-inch disk electrodes spaced 100 mils apart were finally adopted for the following reasons:

(*a*) Spheres have the theoretical advantage that the stress gradient at any point in the electrostatic field between the electrodes can be definitely calculated. With disks, the field directly between the electrodes is of course easily calculated but the stress at the points of maximum stress, namely, at the corners of the electrodes, cannot readily be computed. While this theoretical consideration may be of importance in research investigations, particularly on absolutely pure materials, it does not appear to be of any practical consequence with commercial products because of the very great variation in such products even between successive tests of the same specimen. Disk electrodes have the practical advantage of a considerably lower voltage at breakdown.

(*b*) One-inch disks were adopted instead of ½-in. disks because of the lower voltage required at puncture for a given spacing.

(*c*) A 100-mil gap was adopted as a reasonable compromise between small gaps requiring a low voltage but in which errors in setting are magnified and large gaps requiring a high voltage but having smaller errors due to gap setting.

(*d*) A very important advantage of the 1-in. electrodes with a 100-mil gap was the fact that it was already in quite extensive use. General experience and special investigations by the committee had shown that the 1-in. disks gave practically as consistent results as the other two forms of electrodes which had been discussed, leaving the important advantages of lower voltage requirements and established usage in favor of the 1-in. disks.

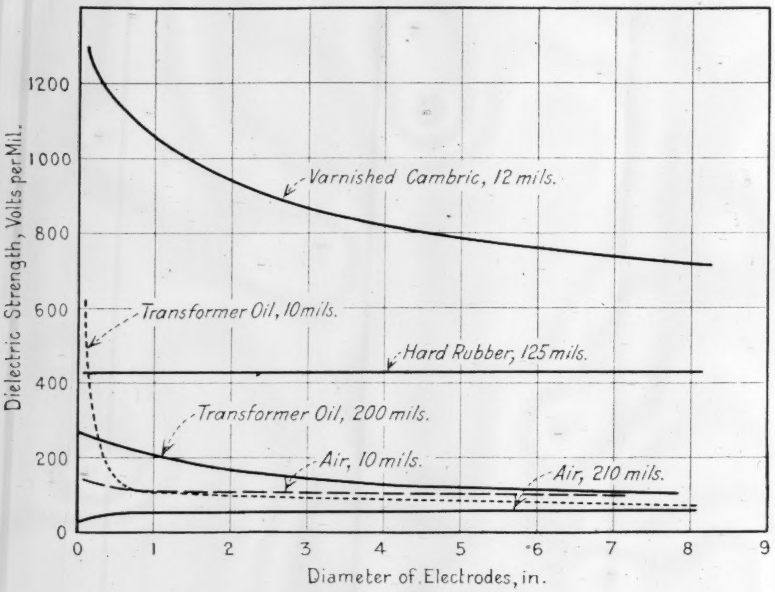

FIG. 1.—Relation of Dielectric Strength to Area of Electrodes.

2. *For Solid Insulation in Sheet and Plate Form.*—Considerations of simplicity and practicability dictate that the electrodes should be flat disks or plates. Circular shape gives the most uniform field distribution and is the obvious choice. The principal question is therefore that of size.

It is well known that the dielectric strength of sheet materials varies with the size of the electrodes—the smaller the electrodes the higher the dielectric strength. The difference is most marked for thin sheets and practically disappears with thick plates. Fig. 1 shows some typical curves for two solid materials, for a transformer oil, and for air. As this figure shows, the curve may be quite different in form for different materials.

It will be seen that in the case of very thin materials, such as varnished cloth, comparatively small differences in the size of small electrodes might have an appreciable effect on the result. For standardization purposes, the size should be one where accidental differences between laboratories will have a minimum effect. With these thin materials, the flat portion of the curve is reached only with electrodes of too large a diameter for general practical use because of the large amount of material that would be required. A diameter of 2 in. was selected by the committee for such thin sheet materials as being sufficiently near the flat portion of the curve for all practical purposes and not requiring an excessive amount of material for a satisfactory test. For thicker materials, where the area effect is less pronounced, smaller electrodes may be used in order to reduce the amount of material destroyed, but the committee has not yet standardized electrodes for plate material.

The thickness of the electrodes has also been prescribed to insure a definite weight on the specimen, the specimen being horizontal and the axes of the electrodes vertical. Sufficient weight is desirable to flatten the specimen and eliminate air pockets and to insure reasonably good contact. Furthermore, the electrodes are of sufficient mass to prevent any appreciable temperature rise in them during a test.

3. *For Thin Materials in the Form of Narrow Strips or Tapes.*—Such materials are usually less than 2 in. wide and as narrow as $\frac{1}{2}$ in. It is evident that 2-in. disk electrodes could not be used. To prevent flashover around the edge of the electrodes, they must be as small as possible and either immersed in a liquid of high dielectric strength or mounted in a suitable holder of insulating material between which the material is tightly clamped. It is desired to avoid immersion in oil in order to make results as comparable as feasible with other tests which do not have to be made under oil. Consequently, electrodes $\frac{1}{4}$ in. in diameter with the edges rounded to a radius of $\frac{1}{32}$ in. and mounted in blocks of insulating material between which the specimen is tightly clamped were adopted. The Tentative Method of Test for Dielectric Strength of Sheet and Tape Insulating Materials Under Momentary Dielectric Stress (D 149 - 23 T)[1] includes illustrations of two suggested clamping arrangements.

While rounded corners are prescribed for the 2-in. electrodes, it does not appear that this is necessary. A series of tests reported elsewhere in this report shows that the average puncture value is the same with square corner electrodes as for those with rounded corners. Nevertheless, prescribing a definite rounded corner eliminates the danger of burrs being left on the electrodes and insures uniformity of the electrodes. Furthermore, at very high voltages the effect of sharp corners may be more marked.

The question may be asked as to why still another method of making the voltage test is used for adhesive and rubber tape. Adhesive tape is wrapped on a brass rod or tube and potential applied to the rod or pipe and tin-foil wrapped on the outside. Rubber tape is tested between two spherical electrodes. But it is to be noted that these tests are for acceptance purposes only and not for determining the dielectric strength. All that is required in this class of material (particularly adhesive tape) is that they withstand a certain relatively moderate voltage and that the actual dielectric strength is not ordinarily determined because it is of much less importance than in the case of high-voltage insulating materials. Hence methods of making the "proof" test were adopted which were as simple and inexpensive as possible.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 817 (1923).

4. *For Solid Insulating Materials which are put in Position when Hot and Liquid.*—From the standpoint of simplification, the gap adopted for liquid insulations (1-in. disks, 100 mils apart) should be used. But ½-in. spheres, 100 mils apart, were decided upon for the following reasons:

(*a*) Greater freedom from danger of gas bubbles collecting, or shrinkage voids forming, between the electrodes.

(*b*) Most of the compounds are difficult to remove from the test cup and electrodes, so that a form sufficiently inexpensive to justify discarding after the test is desirable. This is much more feasible with spherical (or hemispherical) electrodes because slight lack of alignment of the axes is not seriously objectionable. With disk electrodes which must be reasonably parallel, a comparatively elaborate mounting is necessary and it cannot be made sufficiently inexpensive to justify discarding after a single test.

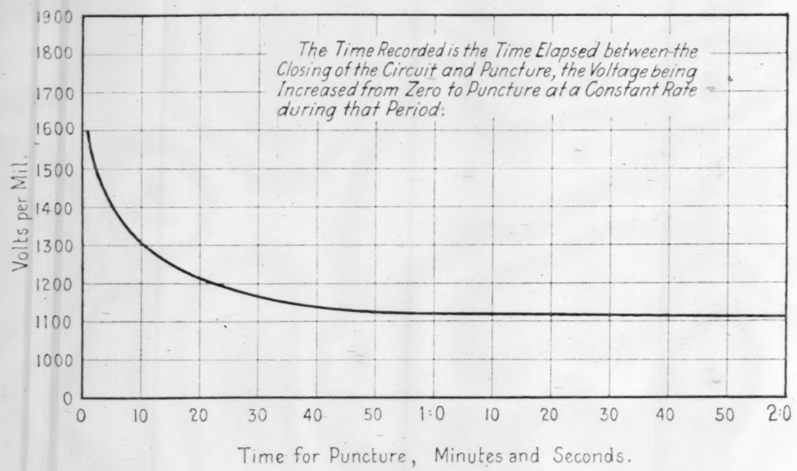

FIG. 2.—Relation of Dielectric Strength to Rate of Increase of Voltage.

The time recorded is the time elapsed between the closing of the circuit and puncture, the voltage being increased from zero to puncture at a constant rate during that period.

(*c*) The objection may be raised that 100-mil spacing requires in some cases a very high potential—over 100,000 volts to break down some materials. While this requires more than the simple equipment used for oil testing, it was considered desirable to keep constant as many variables in our various standard gaps as possible, hence the recommendation of 100 mils as in the gap for oils. Furthermore, an error in the gap spacing due to the original setting or possible displacement when the compound solidifies has a less effect at 100 mils than at a smaller spacing.

The question may be asked, how soft compounds, such as petrolatum, shall be tested. Since it is readily removed from the test cup, it can be tested in the standard gap for oils, that is, 1-in. disks with 100 mils separation. Which gap should be used would apparently depend upon the circumstances. If comparison is to be made with liquid insulations, as, for example, in investigations of cable impregnating compounds which have been tested with the disk gap, then the oil gap should be used for the petrolatum. But if comparison is to be made with hard compounds, as in investigations of cable joint splicing compounds, then the ½-in. sphere gap with 100-mil spacing should be used.

Variation of Dielectric Strength with Time.—The dielectric strength of insulating materials varies greatly with the time during which the potential is applied—the shorter the time the higher the breakdown voltage. The effect is most marked for short periods, the dielectric strength falling off rapidly in the first few seconds, often being 25 per cent or more higher for two or three seconds than for one minute as shown by a typical curve for varnished cambric in Fig. 2 showing the effect on dielectric strength of the rate of raising the voltage. But it may continue to decrease gradually for hours as indicated by the typical curves in Fig. 3 which show the effect of time of application of the voltage. This characteristic of insulating materials raises one of the most perplexing problems in the standardization of methods of testing such materials.

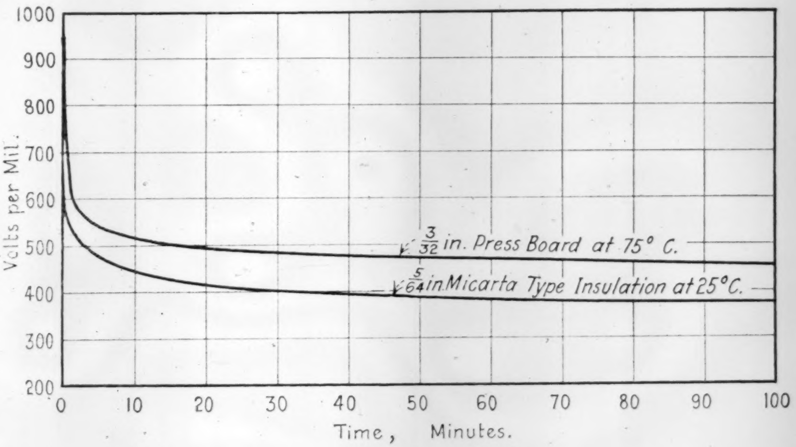

FIG. 3.—Relation of Dielectric Strength to Time.

The exact fundamental cause of failure of insulation under electrical stress is not yet clearly understood. It seems very probable, however, that it is usually due to one or more of three effects:

1. Generation of heat within the insulation due to absorption of energy. As the temperature rises, the amount of energy absorbed increases very rapidly,

thus causing a further rise in temperature so that finally combustion of the material takes place. It is localized at a spot because no insulation is absolutely homogeneous and some one path between the electrodes is weaker than the others and the temperature will rise fastest along it.

2. Chemical action, as in the case of insulation containing gas-filled voids where the ionization of the gas produces nascent oxygen, nitrous oxide or other chemically destructive products, or as in the case where the chemical composition of the material is changed to one of lower resistivity and therefore higher energy loss which eventually causes destruction by combustion.

3. By direct mechanical disruption due to mechanical stresses set up by the electrostatic field or to gases suddenly produced within the material by the sudden application of potential.

The first two of the above classes of failure are progressive and involve the element of time. Hence the problem is to obtain in the laboratory in a practicable length of time, data by which the performance in service for a period of years may be predicted. It is evident that the procedure must be arbitrarily determined. Furthermore, one procedure will not suffice for all purposes for which dielectric strength data are desired. Therefore three standard methods have been proposed as follows, of which mention is made in the body of the report:

A, Short-Time Dielectric Strength Test;
B, Step-by-Step Dielectric Strength Test;
C, Endurance Dielectric Strength Test.

Thickness.—The dielectric strength of insulating materials usually decreases with increase in thickness. In many materials, the dielectric strength is proportional to two-thirds to three-quarters power of the thickness. It would therefore be desirable for standardization purposes to adopt a standard thickness for dielectric strength tests of all materials so that all dielectric strength figures would be comparable. But this is only practicable for liquid and semi-liquid insulations and those which are formed in position by being poured while in a hot liquid state or by molding processes. The A.S.T.M. standard for these materials is 100 mils except for varnishes which are used as films and therefore tested as such, and molded materials where the thickness of about 200 mils is determined by the test cup which is used as a test specimen and which was designed primarily to test the molding properties of the material.

In the case of materials which are made up in various thicknesses and afterward applied in position, it has not been found practicable to standardize a test using more than one thickness of the material. The thickness of the material should always be stated with the results of the test.

Variation of Dielectric Strength with Temperature.—The dielectric strength usually decreases with increases in temperature. Some materials decrease very little while others decrease markedly. Fig. 4 shows some curves for certain electric cable splicing compounds which are liquid at high temperatures but solid at room temperature. The standard temperature in the A.S.T.M. standards is room temperature except where the material is likely to show large changes with temperature and a knowledge of that characteristic is important, as in the case of cable splicing compounds. Hence the prescribed test methods for such materials as given in the Tentative Methods of Testing Cable Splicing and Pothead Compounds (D 176 – 23 T)[1] recommends making tests over the temperature range –25 to +100° C. It is evident that in any case where an insulation is to be subjected to any appreciable range of temperatures, tests at various temperatures should be made.

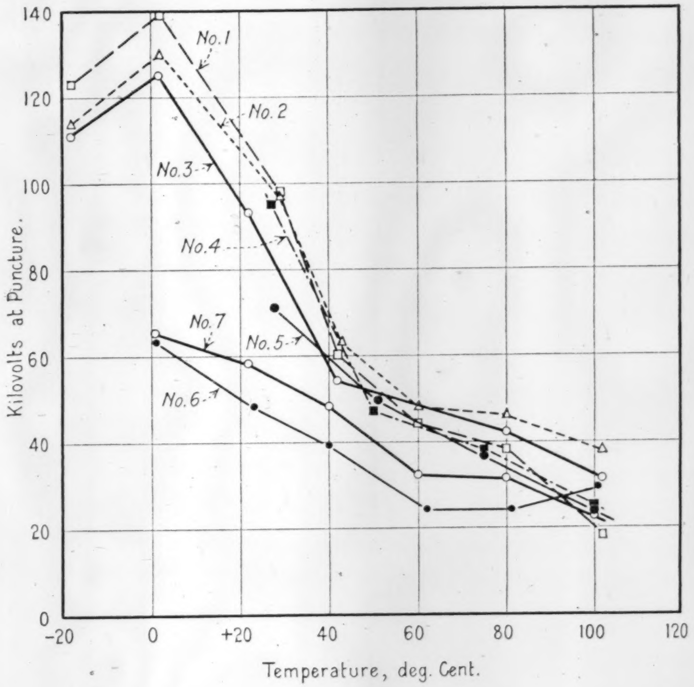

FIG. 4.—Relation of Breakdown Voltage to Temperature.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 848 (1923).

Variation of Dielectric Strength with Frequency.—In general, the dielectric strength of insulating materials decreases with a marked increase in frequency due probably to the greater energy loss and the consequent higher temperature. But the difference between the dielectric strength at 25 cycles and that at 60 cycles—the standard commercial frequencies—is negligible in comparison with the inherent low order of precision attainable in this class of measurements. Therefore the standard procedure of permitting tests to be made at any frequency not exceeding 100 cycles is justifiable.

Surrounding Medium.—The dielectric strength of some materials may vary considerably with the surrounding medium, particularly where a high voltage is required to puncture the material. In other words, a test made with the specimen under oil may give quite a different result from one made in air, even when there is no absorption of oil by the material. Of course porous materials may absorb oil, thereby possibly increasing the dielectric strength. The greater convenience of tests in air makes that procedure preferable for standardization purposes where the voltage does not exceed about 25 or 30 kilovolts. But for higher voltages, it is desirable to eliminate the excessive brush discharge around the electrodes which takes place in air and which may affect the dielectric strength due to heating, especially in the longer-time tests. If the material is non-absorbent, this is accomplished by making the tests under oil which also permits the use of smaller specimens by shortening the flashover path around the specimen. Furthermore, many materials are permanently under oil in service so that tests under that condition are desirable. It is probable therefore that the committee will consider standardizing the voltage at which tests shall be made under oil and the general grade of oil which shall be used.

Wave Form.—The dielectric strength is more or less a function of the maximum *instantaneous* value of the voltage applied to the specimen. That is, with wave shapes having the same mean effective value, the value of dielectric strength obtained will depend upon the maximum instantaneous values of the wave. The relation is obscure, however, and it is not feasible to apply a correction factor so that all dielectric strength tests should be made with a voltage having a substantially standard wave shape which, according to the Standards of the American Institute of Electrical Engineers, is a sine curve. With such a voltage, the ratio of the maximum instantaneous value to the mean effective value is $\sqrt{2}$ or 1.41.

APPENDIX III

DIELECTRIC POWER LOSS AND POWER FACTOR OF THE CHARGING CURRENT IN INSULATING MATERIALS

Dielectric Power Loss.—Electrical insulating materials are generally defined as materials which will not conduct electricity. For practical purposes, this statement is in a general way correct. But, strictly speaking, there is no such material as a true non-conductor of electricity, for even the best of our insulating materials conduct some electricity, although the amount may be extremely small and far beyond the detection of our most sensitive measuring facilities. That is to say, a current will flow when any material is subjected to a difference of electrical potential and power will be dissipated in it. The classification of material into conductors and non-conductors is therefore an arbitrary one based on practical considerations.

The flow of alternating current through any insulating material is accompanied by an expenditure of energy which is wasted and therefore undesirable. However, in most practical applications the economic feature of such loss is of little importance. A much more important objection is that it appears in the form of heat which acts to increase the temperature of the material. Most commercially practicable insulations have a definite maximum temperature limit within which physical and electrical deterioration takes place in a definite time and beyond which deterioration takes place in a shorter time. Consequently, the current carrying capacity or rating of the apparatus is very likely to be determined by the allowable temperature in the insulation. The larger the proportion of the heating of the insulation which is due to dielectric power losses, the smaller the proportion which may be permitted by the conductor losses in the apparatus and consequently the lower the capacity or rating of the apparatus.

With the marked increase in voltage of electrical apparatus in the past few years, a knowledge of the loss in insulations has become more and more necessary because higher and higher voltage stresses are being applied to the insulating materials and the loss increases rapidly with increase in voltage stress. And this increase in loss may cause serious decrease in dielectric strength due to excessive temperature rise. Hence the determination of this loss is becoming an important item in the testing of insulating materials.

What is the Nature of Dielectric Power Loss?—This question cannot as yet be answered. It is highly probable that in most insulations a considerable portion, at least, of the dielectric power loss is I^2R loss $\left(\frac{E^2}{R}\right)$, but it cannot be calculated in the ordinary way. This may be due to the complex character of insulations and our inability to express an equivalent electrical circuit in terms of the known and measurable properties of resistance and capacitance. If a given piece of insulation is subjected to electrical tension and it is assumed to be equivalent to an ordinary electrical circuit containing resistance and capacitance in series, the dielectric power loss would be, with sinusoidal e.m.f. and current:

$$\frac{E^2}{\sqrt{R^2 + \left(\frac{1}{2\pi f C}\right)^2}} \cos \phi \ldots\ldots\ldots\ldots\ldots (1)$$

where $E=$ applied voltage, $R=$ resistance, $C=$ capacitance, $f=$ frequency and $\cos \phi =$ power factor. But the actual measured loss is far greater than that obtained by calculation with this formula if the value of R is taken as the resistance obtained by the ordinary measurement with direct current.

If the equivalent circuit is assumed to be resistance and capacitance in parallel instead of in series, the formula for the loss becomes

$$\frac{E^2}{R}\sqrt{1 + (2\,\pi f\,C\,R)^2} \cos \phi \ldots\ldots\ldots\ldots\ldots (2)$$

The loss calculated with this formula is frequently nearer the measured value than that obtained by Eq. 1. But in general the dielectric power loss does not follow any such simple law as either of these.

There is apparently no direct relation between the resistivity (specific resistance) of any insulation as ordinarily measured with direct potential and the dielectric power loss obtained with alternating potential. All that can be said is that in a very general way the high-resistance materials have a lower loss. But the ratio of the two varies over a wide range so that neither the dielectric power loss nor the power factor can be even roughly determined from the resistivity.

Some writers have ascribed dielectric power loss to a hysteresis effect, that is, the rapid alternate positive and negative electrification of the molecules of the insulation similar to that which occurs in magnetic materials when subjected to rapidly reversing magnetizing force. But this theory is not entirely supported by experimental evidence. For instance, the loss is usually not proportional to the frequency of reversal with commercial frequencies, most insulations showing only relatively little increase in dielectric loss with increase in frequency. At high frequencies, the loss in some materials increases somewhat less rapidly than the frequency but in others considerably more rapidly than the first power of the frequency. But it is to be noted that an increase in loss with increase of frequency could be explained by the series resistance - capacitance theory (Eq. 1) as simply increased I^2R loss due to the greater current through the series resistance.

Other authorities consider that dielectric power loss is associated with the phenomenon of absorption in dielectrics, that is, the property which, when a constant potential (*i. e.*, direct current) is applied, causes the current to approach very slowly its final value and not practically instantly as in an ordinary conductor circuit.

So that while a number of different theories have been developed in explanation of the nature of dielectric power loss and several investigators have developed more or less complicated mathematical formulas which seem to more or less fit the experimental results obtained in isolated cases, a generally acceptable explanation which is broadly applicable has not yet been proposed. It is necessary, therefore, to consider that dielectric power loss (and power factor) is an independent property which cannot be stated in terms of the resistivity, dielectric constant, or other known physical properties.

Use of Power Factor.—The dielectric power loss in any one kind of insulation will vary with the thickness, the size and shape of the electrodes, the temperature and the voltage applied. For standardization purposes, the dielectric power loss should be referred to a unit basis such, for example, as a centimeter cube of the material. But this is not feasible even when the dimensions permit calculation because the loss may not always be assumed to be proportional to the thickness even with a constant stress gradient. It is therefore more suitable when comparing insulations to use the power factor of the dielectric (ratio of dielectric power loss in watts to the product of the applied volts and the current in amperes) since it will be independent of any of the dimensions or of the shape and size of the specimens and of the electrodes. Furthermore, in a high-grade homogeneous insulation, it will be practically independent of the voltage up to values approaching the rupturing voltage. However, the power factor is directly proportional to the quotient of the dielectric loss divided by the dielectric constant (specific inductive capacity) so that when comparing the power factors of different insulations, the values of the dielectric constant should also be noted.

Variation of Dielectric Power Loss and Power Factor with Temperature.—The dielectric power loss and therefore the power factor of insulations are very sensitive to temperature changes, usually increasing rapidly with increase of temperature. Two insulations which may have nearly the same loss and power factor at room temperature may differ several hundred per cent at operating temperatures, say 80° C., as shown in Fig. 1, where the dielectric loss and power factor in impregnated paper insulation on two samples of high-voltage cable (one obsolete for comparison and one recent) have been plotted against temperature.

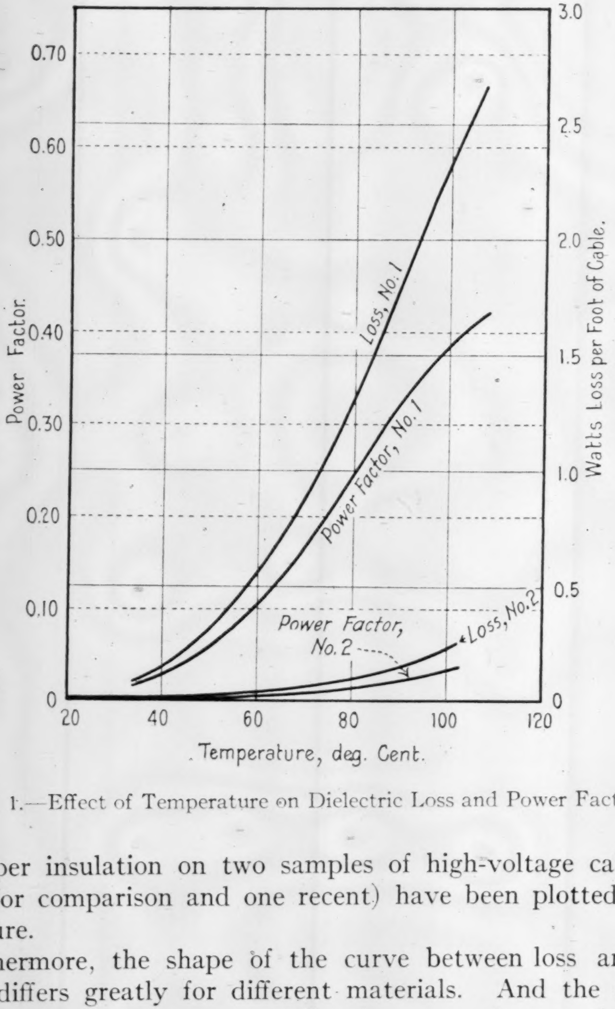

FIG. 1.—Effect of Temperature on Dielectric Loss and Power Factor.

Furthermore, the shape of the curve between loss and temperature differs greatly for different materials. And the shape is important because the more rapidly the curve rises at the higher temperatures, the less is the emergency overload capacity of the apparatus. Also, where the heat dissipation is restricted as in underground power cable, the temperature is more quickly reached where cumulative heating of the insulation occurs (that is, the temperature where heat is generated faster than it can be dissipated) and self-destruction results. Consequently, it is desirable that the dielectric losses not only be small but that the increase with rise in temperature be a minimum.

Variation of Power Factor with Voltage.—In a strictly homogeneous insulation, the power factor as a general rule will be practically constant and independent of the voltage so long as the temperature is constant. But there will always be some loss when potential is applied and therefore some temperature rise. Whether it is sufficient to affect the power factor depends upon the magnitude of the power loss, the length of time that the voltage is applied and the heat dissipating ability of the insulation. If a gradual increase in the power factor takes place as the potential is increased, it may be assumed that it is due to temperature rise.

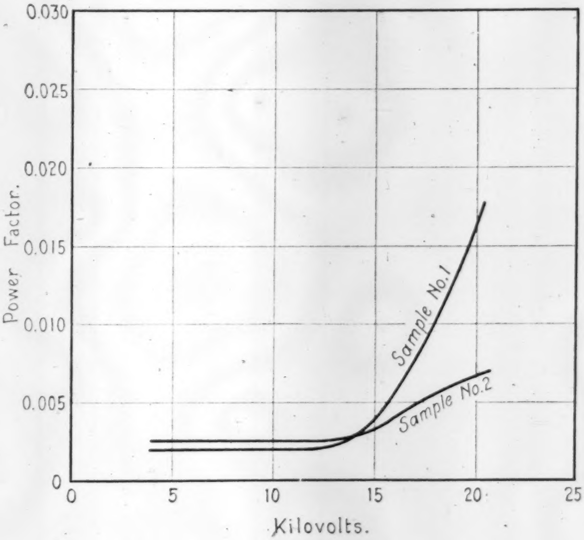

FIG. 2.—Variation of Power Factor with Voltage.

But there are very few strictly homogenous materials. Most solid insulations are more or less porous, and in the case of laminated insulations, there will be more or less air between layers. Air is a reasonably good insulator so long as it is not over-stressed. However, it becomes ionized and breaks down at a very definite voltage stress. As soon as ionization begins, energy is expended and the power loss increases. The presence of gas-filled voids in solid insulations is rather generally, but not universally, believed to be indicated when the dielectric loss and power factor suddenly increase above the normal rate as the voltage is increased, as shown in Fig. 2, where the power factor of the insulation in two samples of paper insulated cable has been plotted against voltage. This point of sudden change is generally referred to as the ionization point and is considered a significant characteristic on the theory that ionization of the gas in the voids weakens the insulation due to chemical action or to the development of local hot spots or a combination of both. It is standard practice, therefore, to eliminate air and gas as much as possible from the pores of insulation to be used on high-voltage apparatus by vacuum treatment and impregnation with a liquid insulating material.

It has been suggested that the thoroughness of impregnation of such materials may be judged from the rate of increase in power factor with increase in voltage. In other words, it is proposed that an important characteristic of insulating materials, namely, freedom from voids, can be determined from the change in power factor with a given change in voltage stress in the material. The practical importance of such a test is yet to be completely demonstrated because there is considerable evidence that insulations have been in service for many years at voltage stresses materially above the ionization point and no trouble has been experienced. Nevertheless, other things being equal, the insulation with the least evidence of ionization is preferable.

Methods of Measurement.—The problem of measuring dielectric power loss is one of measuring a definite physical quantity in terms of a definite unit. That is, it is one of measuring power. Therefore, any method may be employed which will correctly measure a small amount of power at low power factor and high voltage. This is different from the determination of dielectric strength where the result depends upon the conditions under which the test is made, and standardization of the method of test becomes essential. In power loss measurements, standardization is not necessary for that reason, but, as a matter of simplification in the standardization of a complete list of tests of insulating materials, it may be desirable for the committee to consider recommending the adoption of one or two methods as standard.

There are two general classes of methods of measuring dielectric loss and power factor, namely, (*a*) bridge methods and (*b*) direct measurement with a wattmeter. In both methods, the specimen is placed between two metal plates or concentric cylinders and the loss is calculated from the constants of the condenser so formed or measured directly.

Bridge Methods.—In these methods the loss and power factor are calculated from the apparent resistance and capacitance of the condenser formed with the material as the dielectric. Bridge methods have the advantage of high precision because they are not only null methods, but the results are in terms of accurately determinable standards of resistance and capacitance or inductance.

Many of the standard bridge methods shown in textbooks on electrical measurements may be adapted to tests of this kind. But these methods were developed for measurements at low potentials, and while such measurements on commercial insulating materials serve a useful purpose, such as, for example, control tests of a given product, investigational tests should be made over a range of voltage stresses up to values well above the maximum at which the material is to be used. When tests are made at high voltages, the precautions which always have to be taken to guard against errors become especially important. There are several causes for these errors, the principal ones of which are:

1. Inductance or capacitance in the standard resistors and a defect angle in the condenser (that is, the angle by which the phase angle of the condenser differs from 90 deg.). Errors due to these causes must either be known or eliminated by removal of the causes, that is, by proper design and construction of the resistors and condensers.

2. Capacity currents and leakage currents to ground and also between the various parts of the bridge arrangement. Errors due to capacity currents must be eliminated by suitable and proper electrostatic shielding. Errors due to leakage currents are eliminated by suitably insulating the apparatus and circuits from ground.

3. Inductive effects on the detector and on the bridge circuits due to external fields. These errors are avoided by properly arranging the current leads to the apparatus, the detector circuit and the bridge circuits with reference to the current leads to the bridge.

A convenient and satisfactory practical bridge method of tests of this kind was described in the 1923 report of Committee D-9.[1] A discussion of high-voltage bridge methods, including the Schering bridge much used in Europe for these tests, is given in an article in "Beama" (London, August, 1923) by L. Hartshorn of the National Physical Laboratory of England.

Wattmeter Methods.—The dielectric loss of a sample arranged in the form of a condenser may be measured directly by means of a high-sensitivity reflecting wattmeter. Wattmeters of the electrodynamometer type, the electrostatic type[2] and the cathode-ray-tube type[3] have been successfully used for these measurements. The power factor is obtained either by (*a*) measuring the total current with the same instrument or a similar one used as an ammeter and calculating from the total volt-amperes or (*b*) by measuring the reactive volt-amperes with the wattmeter by shifting the excitation voltage 90 deg.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol 23, Part I, p. 456 (1923).

[2] D. M. Simmons and W. S. Brown, "The Quadrant Electrometer for the Measurement of Dielectric Loss," Midwinter Convention, Am. Inst. Electrical Engrs., Philadelphia, February, 1924.

[3] J. P. Minton, "An Investigation of Dielectric Losses with the Cathode Ray Tube," *Transactions*, Am. Inst. Electrical Engrs., Vol. 34, p. 1627 (1915).

A specimen of considerable size is usually necessary to obtain a measurable dielectric power loss. The usual precautions in the way of shielding and guarding are necessary. The electrostatic and the cathode-ray-tube instruments have the advantage over the electrodynamometer wattmeter of permitting the measurements to be made up to the puncturing voltage.

Test Specimen.—The matter of contact of the test specimen with the electrodes is very important. Fig. 3 shows the effect of air spaces between the specimen and the plates. The best practicable and convenient type of electrode which will insure reasonably intimate contact is mercury. The specimen can be floated on mercury and an upper electrode formed by a pool of mercury confined by a suitable annular ring of insulating material inside of which is a ring of mercury which forms the guard circuit.

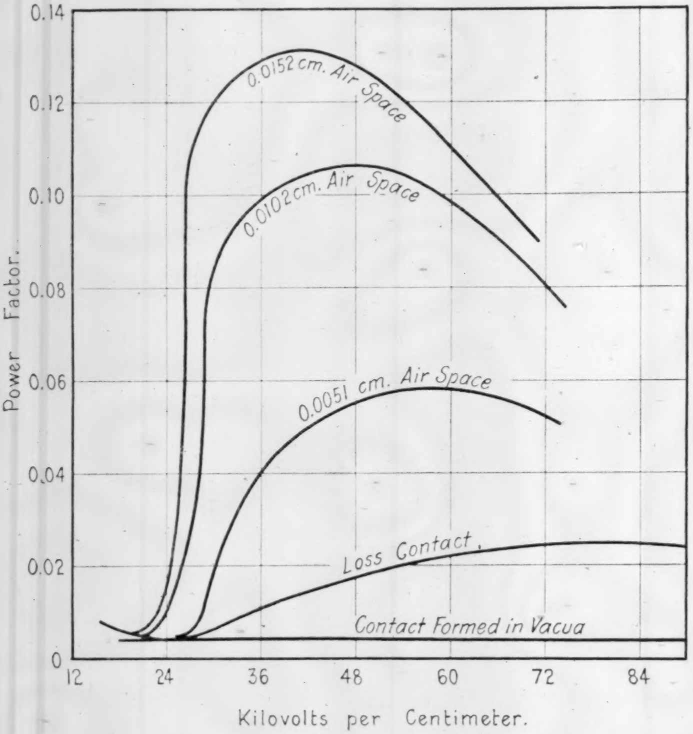

FIG. 3.—Effect of Poor Contact in Power Factor Tests.

Taken from "Corona in Air Spaces in a Dielectric," by J. E. Schrader, Annual Convention of the American Institute of Electrical Engineers, June, 1922.

APPENDIX IV

A METHOD FOR ESTIMATING ACIDITY OF OILS

By D. C. Cox[1]

In titrating the acidity of oils with 0.01 *N* aqueous caustic soda solution and using phenolphthalein as an indicator, several difficulties are encountered. In order to secure homogeneous liquid, the oil must be dissolved in a large amount of a mixture of benzol and ethyl alcohol. Even when thus dissolved, the solution will separate into layers if any considerable amount of the caustic soda solution is added. Consequently, the titration is limited to a few cubic centimeters. As a rule, fresh oils very light in color are almost free from acid. It is customary in such cases to use a 10-cc. sample of oil. When oils are very dark and rather highly acid, it is impossible to use such a large quantity, both because as the titration proceeded, water would separate out and because the end point would be invisible. Consequently, small samples are used in some attempt to avoid these difficulties. The result is extreme inaccuracy in the case of acid oils.

The following method avoids both of these difficulties, enabling a 10-cc. sample to be used in every case, permitting quite high titration values and enabling the operator to determine the end point accurately in all cases.

It should be stated at the outset that such discrepancies as that caused by adsorption of caustic soda by coloring matter or other colloidal substances, are not avoided by this method. The precise quantity which is measured is that volume of alkali which may be added before the hydroxyl ion concentration reaches a point sufficient to produce the pink color in phenolphthalein.

Concentration Cell Methods Applied to Titration of Oils.—Two 150-cc. beakers are placed side by side under two burettes. Ten cubic centimeters of the sample are run into a 100-cc. volumetric flask and made up to the mark with a benzol - ethyl alcohol mixture (equal volumes). This is poured into one of the beakers. Ten cubic centimeters of a neutral oil are made up to 100 cc. in the same way and poured into the other beaker. Five cubic centimeters of a saturated solution of potassium iodide are added to each beaker in order to secure conductivity. The beakers are connected electrically by means of a U-tube filled with a conducting jelly.[1] Into each beaker is placed a spiral of clean platinum wire and these wires are connected to some form of potentiometer. Great sensitivity is not required, for the potential differences are quite appreciable.

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[1] Chemist, Pittsfield Works, General Electric Co.

A few drops of phenolphthalein are added to the blank and 0.05 N sodium ethylate[2] in alcohol is added from the burette until a faint pink color which does not immediately bleach is attained. The potential difference between the electrodes may now be measured. One-half cubic centimeter of sodium ethylate is now added to the beaker containing the sample, the solution is stirred and the potential difference again measured. Thus by steps of 0.5 cc. the titration proceeds. The voltage will be observed to drop quite rapidly. The point where the voltage becomes zero is read as the end point. As the benzol alcohol mixture is not neutral, the titration value of the blank is subtracted from that of the sample. The difference is reported as the number of cubic centimeters of 0.05 N alkali required to titrate 10 cc. of the sample.

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[1] This jelly is prepared by adding 5 cc. of alcoholic solution of potassium iodide to 100 cc. of water, adding to this 2 g. of agar-agar and heating to 80 or 90° C. This is sufficient for six or eight U-tubes made by bending ½-in. glass tubing. They are filled with this solution which quickly sets to a firm highly-conducting jelly.

[2] To prepare this solution, metallic sodium is melted under oil and sucked up into glass tubes. The weight of sodium per inch of tubing is determined and a suitable length for making up the solution desired is cut off with a file and dropped directly into ethyl alcohol. When solution has taken place, the liquid is filtered and standardized. A convenient method for standardization is to titrate the solution against U. S. Bureau of Standards' standard sample of benzoic acid, using phenolthalein as indicator.

REPORT OF COMMITTEE D-10
ON
SHIPPING CONTAINERS

The work of Committee D-10 is largely educational. It furnishes a common ground for a get-together of the container manufacturer, the shipper, and the carrier. The committee is vitally interested in the testing of containers and in the promulgation of specifications for containers which will lessen some of the appalling economic losses that are being borne by the people. Few, if any, know or knowing can comprehend the enormous monetary value of shipping containers and the expense incurred in packing for shipment and the cost of transportation. Some slight idea may be obtained from the statement that after packing, the transportation charges, based on the weight of boxes alone, exclusive of contents, will run into millions of dollars every week.

It would appear that, since wooden boxes have been used since earliest antiquity, by this time we should know all about them. But there have been great changes in the demands made upon the boxes. We are placing our shipping containers under increasingly severe conditions. At no time in past history has there been anything that approached modern transportation either in volume or speed. A relatively few years ago there were no trains, no auto trucks, and no airplanes, which have transformed our mode of living. There are members of this Society who can remember when, in some sections of the United States where strawberries are now on the market in January, even bananas were a curiosity and oranges were indulged in only at Christmas. The changes in design of shipping containers have not kept pace with these changed conditions. However, the packages of to-day are lighter, stronger, and can be made for less money than we could make the types of packages of 10 years ago. Packing methods have improved and the handling of packages is more intelligently done. It is estimated that to pack and handle our present shipments in the old way and to handle and transport them in the types of containers in use when this committee was formed (1914) would cost the people of the United States more than a million dollars a week in excess of present costs.

In manufacturing processes, box-making and the whole lumber industry have kept pace with the times, but they have rested on the assurance that everybody knew lumber and how to use it. As a consequence, lumber has been used in ways it should not have been, with a consequent big economic loss and a growing tendency to use other materials in places where wood by nature is best suited. The problem of the committee has been to counteract this spirit and to develop boxes which will be economical and serviceable under present conditions. Its work has been that of a coordinating agent and as such has had a wide influence.

There are a few lines of work along which particular progress has been made and which should receive especial consideration in this report.

Cooperage.—The sub-committee on cooperage has been working with the Bureau of Explosives in the revision of I. C. C. Specifications 9 and 10. This committee is alive to the possibility of further development in the cooperage industry and the need of more testing, especially on slack cooperage.

Fiber and Corrugated Boxes.—Considerable testing work has been done during the past two years on fiber and corrugated boxes. The industry maintains several testing drums and has done much work in the development of packages and methods of packing for individual commodities.

Since the score is recognized as one of the weakest points of the fiber and corrugated boxes, the Forest Products Laboratory has given considerable time to a study of methods for testing scores, and of the conditions under which the best score can be made. The Mullen test is no criterion of the damage that may have been done to the board in scoring. It is evident that the score may be reinforced but it would appear to be much better to obtain the desired result by eliminating as nearly as practicable the cause of the weakness. The study has not been completed but it is now evident that much will be accomplished along this line.

Crates.—There is no one organization that is primarily interested in crates. Therefore, it has been very difficult to bring the interests together. The box manufacturers make some crates and a few of the lumber companies are giving consideration to the manufacture of knocked-down crates with profit to themselves, to the shipper, and economy to the general public. The Forest Products Laboratory has been developing the details of crate construction which, under various conditions, will give the best results. The more general use of the three-way corner and the diagonal braces has been of material benefit, but much education along this line is needed. There is much to learn about the form and size of pieces and the best methods of

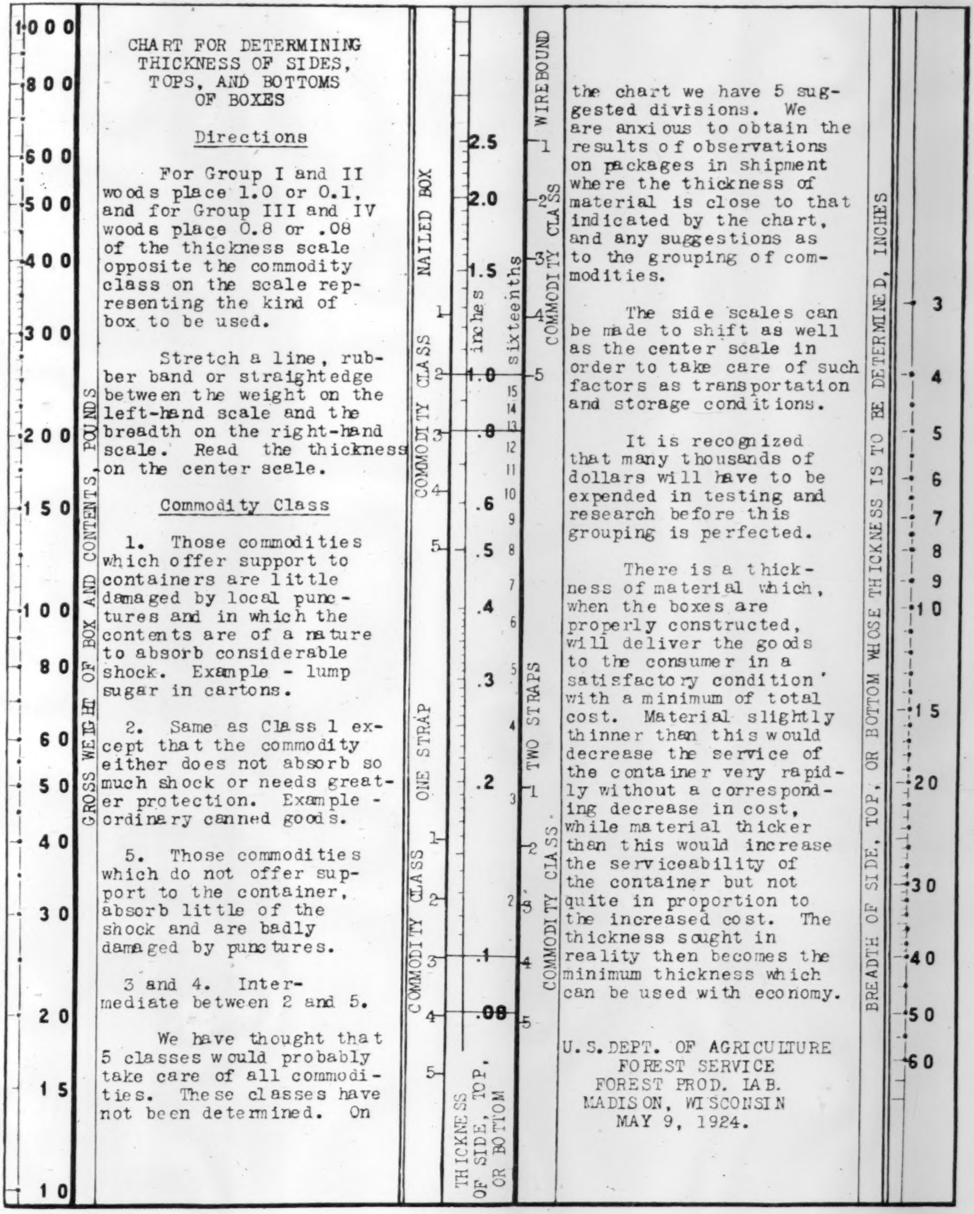

CHART FOR DETERMINING THICKNESS OF SIDES, TOPS, AND BOTTOMS OF BOXES

Directions

For Group I and II woods place 1.0 or 0.1, and for Group III and IV woods place 0.8 or .08 of the thickness scale opposite the commodity class on the scale representing the kind of box to be used.

Stretch a line, rubber band or straightedge between the weight on the left-hand scale and the breadth on the right-hand scale. Read the thickness on the center scale.

Commodity Class

1. Those commodities which offer support to containers are little damaged by local punctures and in which the contents are of a nature to absorb considerable shock. Example - lump sugar in cartons.

2. Same as Class 1 except that the commodity either does not absorb so much shock or needs greater protection. Example - ordinary canned goods.

5. Those commodities which do not offer support to the container, absorb little of the shock and are badly damaged by punctures.

3 and 4. Intermediate between 2 and 5.

We have thought that 5 classes would probably take care of all commodities. These classes have not been determined. On the chart we have 5 suggested divisions. We are anxious to obtain the results of observations on packages in shipment where the thickness of material is close to that indicated by the chart, and any suggestions as to the grouping of commodities.

The side scales can be made to shift as well as the center scale in order to take care of such factors as transportation and storage conditions.

It is recognized that many thousands of dollars will have to be expended in testing and research before this grouping is perfected.

There is a thickness of material which, when the boxes are properly constructed, will deliver the goods to the consumer in a satisfactory condition with a minimum of total cost. Material slightly thinner than this would decrease the service of the container very rapidly without a corresponding decrease in cost, while material thicker than this would increase the serviceability of the container but not quite in proportion to the increased cost. The thickness sought in reality then becomes the minimum thickness which can be used with economy.

U.S. DEPT. OF AGRICULTURE
FOREST SERVICE
FOREST PROD. LAB.
MADISON, WISCONSIN
MAY 9, 1924.

FIG. 1.—Chart for Determining Thickness of Sides, Tops and Bottoms of Boxes.

fastening the ends of each member. Considerable has been accomplished already along these lines, but with literally thousands of combinations of factors to be considered it is evident that a complete solution of all problems connected with crate construction is not near.

As an example of what can be accomplished, blocks placed in the corners of crates so as to give better nailing and more rigidity to the corner have been found almost to double the strength in some very important particulars. At times it is possible to use such blocks to good advantage either in lightening the crate or increasing its strength, while at other times these blocks will be in the way and some other method is necessary.

Wooden Boxes.—During the past two years several thousands of dollars have been spent in an effort to establish the proper thickness of sides, top, and bottom of the nailed wooden box. The Forest Products Laboratory has arrived at the conclusion that the thickness of any side, top, or bottom can be expressed with fair accuracy by the equation

$$T = K\sqrt{\frac{W}{b}}$$

where T = the thickness, K = a quantity not yet fully determined but dependent upon species of wood, nature of commodity, nature of transportation, storage conditions, etc., W = the weight, and b = the width of the side in question. Considerable information is now at hand from which to estimate the value of K for some classes of commodities. It is expected that during the coming year values for K for a number of commodities will be checked up by members of the committee and that next year we will be ready to present general specifications for boxes for some classes of commodities.

A chart has been designed for the simple solution of the above equation. This chart is so simple that even the non-technical person can use it. It consists chiefly of three logarithmic scales, two reading from the bottom up and one from the top down. The left-hand scale has holes corresponding to the gross weight and the right-hand scale has holes corresponding to the width of the side in question, while the center scale, which is movable, carries the thickness of material. This center scale can be set to take care of the species to be used, kind of box, and the class of commodity. A reproduction of the chart with directions for its use is given in Fig. 1.

In case it becomes desirable to consider more factors than can be conveniently handled by shifting the one scale, the other scales can be made to shift for some of the factors.

A similar chart can be made to take care of the nailing, which offers even more variables and factors than the thickness of lumber. The scheme appears to be entirely practicable, but to obtain all the information necessary in relation to all the factors will require years of intensive study.

Strapping.—Considerable work has been done by various organizations in promulgating the use of strapping in accordance with the committee report of two years ago.[1] This has been of immense value in many cases in reducing loss and damage and in securing lighter containers.

Wirebound Boxes.—The Wirebound Box Industry has to a large extent conducted its own investigations. Many of the principles involved in the study of thickness of material and the strapping of wooden boxes are, of course, applicable to wirebound boxes and other types of containers. From the standpoint of fundamental research, however, there is yet much to be accomplished. This is especially true of wirebound crates, a field which appears to offer great possibilities.

Miscellaneous.—In addition to the containers already mentioned there are the basket, hamper, bucket, sack, etc., as well as those made of material other than cellulose. They are all important but can not well be discussed in this report.

Packing.—The matter of packing for shipment is inseparably connected with the design of the container. Often it is possible to reduce breakage and at the same time use a lighter container, merely by making an apparently slight change in the method of packing.

There are some commercial laboratories working on shipping containers. The Freight Claim Prevention Association, the Colonel B. W. Dunn's organizations, the Bureau of Explosives and the Freight Container Bureau are doing excellent work in their respective fields, but the harvest truly is great and the laborers are few.

This report has been submitted to letter ballot of the committee, which consists of 28 members, of whom 25 have voted affirmatively, none negatively, and 3 have refrained from voting.

Respectfully submitted on behalf of the committee,

J. A. NEWLIN,
Chairman.

C. A. PLASKETT,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 483 (1922). See also the Tentative Specifications for Wooden Boxes, Nailed and Lock-Corner Construction (D 68 – 22 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 918 (1922).

REPORT OF COMMITTEE D-11
ON
RUBBER PRODUCTS

Two meetings have been held during the year in addition to the one during the present annual meeting of the Society. Both were held in New York City, one on December 17, 1923, and the other on March 28, 1924.

There are ten tentative standards on rubber products before the Society. The committee recommends that one be revised, two be continued in their present status without revision and that seven be made standards of the Society.

TENTATIVE STANDARDS CONTINUED AS TENTATIVE

Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 - 21 T).—Reference was made in last year's report to the work undertaken under the auspices of the American Engineering Standards Committee to unify the various specifications for wires and cables in general use with a view to setting up an American standard. Committee D-11 is actively cooperating in this work in so far as rubber insulated wires and cables are concerned, and it is expected that a standard specification for that class of wires and cables will be ready during the coming year. In view of possible changes that may be advisable as a result of the work of the Standards Committee, it is recommended that our tentative specifications for this material be continued as tentative.

Tentative Specifications for Steam Hose (D 54 - 21 T).[1]—These specifications have been extensively revised and the proposed revised specifications are appended hereto.[2] They are now in substantial agreement with the specifications of the American Railway Association.

The more important changes from the present specifications are as follows:

> *Construction.*—The number of plies of cotton duck required for the various sizes of hose has been added.
>
> *Physical Tests of Rubber.*—The tensile strength required for the tube has been increased from 600 to 750 lb. per sq. in. before steaming and from 450 to 550 lb. per sq. in. after steaming. The

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 792 (1921).

[2] See p. 1059.—Ed.

limit on maximum elongation has been removed. An additional limitation has been included, namely, the maximum percentage decrease, after steaming, from the original values of tensile strength and elongation. It is obvious that the amount of change in these properties should be limited as well as the final values.

Hydrostatic Test.—A hydrostatic test has been added.

It is recommended that the revised specifications be accepted for publication as tentative to replace the existing tentative specifications.

Tentative Specifications for Rubber Insulating Tape (D 119 – 22 T).—While the committee has no changes to offer in these specifications at this time, the committee considers it advisable to continue the specifications as tentative because of an additional test (adhesion) which has been proposed and which is being investigated.

TENTATIVE STANDARDS RECOMMENDED FOR ADVANCEMENT TO STANDARD

The committee recommends that the following tentative standards be advanced to standard without change:

(*a*) Tentative Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 – 22 T);[1]

(*b*) Tentative Specifications for Wrapped Air Hose for Use with Pneumatic Tools (D 46 – 23 T);[2]

(*c*) Tentative Specifications for Rubber Belting for Power Transmission (D 53 – 23 T);[3]

(*d*) Tentative Specifications for Wrapped Cold Water Hose (D 177 – 23 T);[4]

(*e*) Tentative Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 – 23 T);[5]

(*f*) Tentative Methods of Testing Rubber Products (D 15 – 23 T).[6]

Tentative Specifications for Braided Air Hose for Use with Pneumatic Tools (D 60 – 23 T).[7]—The committee recommends that the following minor change be made in Section 4 (*a*) to permit the use of two plies instead of three plies in $\frac{1}{2}$-in. hose:

Section 4 (a).—Change the first sentence from its present form: namely,

> "The reinforcement shall consist of three plies of braided cotton evenly and firmly woven over the rubber tube."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 931 (1922).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 852 (1923).

[3] *Ibid.*, p. 860.

[4] *Ibid.*, p. 864.

[5] *Ibid.*, p. 867.

[6] *Ibid.*, p. 870.

[7] *Ibid.*, p. 856.

to read as follows:

"The reinforcement shall consist of plies of braided cotton evenly and firmly woven over the rubber tube,—two plies for ½-in. hose and smaller and three plies for ⅝-in. hose and larger."

It is recommended that the specifications as revised be adopted as a standard of the Society.

NEW TENTATIVE STANDARDS

The committee has no new tentative standards to offer nor has it any under development. The field appears to be covered so far as the principal rubber products used in engineering applications are concerned. No suggestions or requests for specifications have been received during the year and the committee has no additional ones in prospect except possibly one for hose to be used for transferring oil or gasoline.

MISCELLANEOUS

The only activity which the committee now has in hand is the matter of performance tests of rubber products. This is a very large subject and much experimental work will have to be done before the committee will be prepared to make any recommendations. It is at present investigating several proposed abrasive tests, an oil and gasoline test and a durability test for belting. The Geer Life Test for rubber products has not yet been proved to be an acceptable test for general standardization although it has been found very useful by individual users on particular products.

The following is the result of the letter ballot vote of the committee, consisting of 34 members, on the recommendations made in this report:

Item	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF TENTATIVE STANDARDS			
Tentative Specifications for Steam Hose (D 54 - 21 T)	23	1	10
II. TENTATIVE STANDARDS RECOMMENDED FOR ADOPTION AS STANDARD			
Tentative Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 - 22 T)	21	0	13
Tentative Specifications for Wrapped Air Hose for Use with Pneumatic Tools (D 46 - 23 T)	24	0	10
Tentative Specifications for Rubber Belting for Power Transmission (D 53 - 23 T)	23	1	10
Tentative Specifications for Wrapped Cold Water Hose (D 177 - 23 T)	24	0	10
Tentative Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 - 23 T)	25	0	9
Tentative Methods of Testing Rubber Products (D 15 - 23 T)	24	0	10
Tentative Specifications for Braided Air Hose for Use with Pneumatic Tools (D 60 - 23 T), as revised	23	0	11

This report has been submitted to letter ballot of the committee, which consists of 34 members, of whom 26 have voted affirmatively, none negatively, and 8 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. M. FARMER,
Chairman.

C. B. MARTIN,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Methods of Testing Cotton Rubber-Lined Fire Hose, proposed in 1922, and subsequently amended in 1923, were approved at the annual meeting, as recommended in this report, and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The Tentative Specifications for Adhesive Tape, for Wrapped Air Hose for Use with Pneumatic Tools, for Rubber Belting for Power Transmission, for Wrapped Cold Water Hose and for Rubber Matting for Use Around Electrical Apparatus were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications appear in the 1924 Book of A.S.T.M. Standards. The Tentative Specifications for Braided Air Hose for Use with Pneumatic Tools, amended as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The specifications, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Steam Hose were approved at the annual meeting, as recommended in this report. The tentative specifications, as thus revised, appear on page 1059.

REPORT OF COMMITTEE D-13
ON
TEXTILE MATERIALS

Committee D-13 on Textile Materials held two meetings during the past year. The fall meeting was held at the Society's headquarters in Philadelphia on October 26, 1923, and the spring meeting was held at the U. S. Bureau of Standards, Washington, D. C., on March 7 and 8, 1924. Both meetings were well attended by members and there was a large attendance of guests.

Three new sub-committees were organized during the past year as follows:

Sub-Committee X on Cement Bag Test Methods and Specifications;
Sub-Committee XI on Test Methods and Specifications for Knit Goods;
Sub-Committee XII on Test Methods and Specifications for Woolens.

Sub-Committee X on Cement Bag Test Methods and Specifications was organized for the development of test methods and specifications for Osnaburg cement bags. It is made up of representatives of Osnaburg manufacturers, cement bag manufacturers, and cement manufacturers. This sub-committee has held several well-attended meetings and has developed Tentative Specifications and Methods of Test for Osnaburg Cement Sacks as appended hereto,[1] which are submitted by Committee D-13 to the Society for acceptance as tentative standard.

Sub-Committee XI on Test Methods and Specifications for Knit Goods and Sub-Committee XII on Test Methods and Specifications for Woolens have held meetings and have outlined the work to be undertaken during the coming year to cover principally the development of test methods and specifications for knit goods and woolens. The work of these two sub-committees will result in a broadening of the scope of the activities of Committee D-13 in the textile field. The need for standards in these two branches of the textile industry is recognized, and so there may be the closest cooperation between Committee D-13 and other organizations in the textile industry interested in the development of such standards, several associations representing the knitting and woolen industries have taken out memberships in the Society.

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[1] See p. 1079.—Ed.

Committee D-13 submits to the Society three new standards, (1) Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns, (2) Tentative Specifications for Tolerances and Test Methods for Cotton Sewing Threads, (3) Tentative Specifications and Methods of Test for Osnaburg Cement Sacks, all appended hereto[1] for publication as tentative, two revisions, (1) Tentative Specifications for Tolerances and Test Methods for Cotton Yarns and Cords (D 180 - 23 T),[2] appended hereto[3] in their proposed revised form, (2) Tentative Specifications for Tolerances for Hose Ducks and Belt Ducks (D 181 - 23 T).[4]

The following revisions are recommended in the Tentative Specifications D 181 - 23 T:

Section 11.—Change from its present form: namely,

> "11. The average warp crimp and the average filling crimp shall be not more than 10 per cent over or under the specified crimp percentage."

to read as follows:

> "The average warp crimp shall not be more than 10 per cent over or under the specified crimp percentage, and the average filling crimp shall not be more than 20 per cent over or under the specified crimp percentage."

The committee recommends that the specifications as revised be continued as tentative.

The revisions of the Standard Methods of Testing Cotton Fabrics (D 39 - 20) proposed in 1923[5] are recommended for adoption as standard.

The development of the Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns has rather an interesting origin. For many years users of electrical cotton yarns, particularly magnet wire manufacturers, have purchased this commodity on specifications which, with other requirements, included the minimum tensile strength. A great deal of difficulty was experienced in the testing of these yarns and wide discrepancies often occurred between results obtained by the manufacturers and the consumers. This was partly due to the fact that manufacturers were making tests on single yarns while consumers were testing multiple wound ends.

Investigation brought out the fact that a great many differences in testing conditions existed, and in an effort to standardize the test methods, with the cooperation of the U. S. Bureau of Standards, a committee was appointed by Mr. C. J. Schnelle representing the Acme Wire Company which included five buyers, five suppliers, a representative of the Bureau of Standards and of the A.S.T.M.

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[1] See pp. 1071-1080.—Ed.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 898 (1923).

[3] See pp. 1066.—Ed.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 902 (1923)

[5] *Ibid.*, p. 973.

At a meeting of this committee held in March, 1923, a report covering experiments and investigations made by the Bureau of Standards was discussed and a sub-committee, consisting of K. B. Cook, representing the A.S.T.M., Chairman, H. M. Remington representing the supplier, and C. F. Hood representing the buyer, was appointed and instructed to prepare tentative test methods for electrical yarns along the lines approved during the discussion. At the next meeting of the general committee held in May, 1923, the sub-committee's recommendations were discussed.

The importance of standards for testing yarns for the electrical industry was so obvious, and the work involved in the development of such test methods so nearly parallel with the work of Committee D-13 on other types of yarn, that it was decided to transfer further activity along this line to Committee D-13 on Textile Materials of the American Society for Testing Materials. Practically all the members of this original group have taken out memberships in the Society and are functioning as a sub-committee of Committee D-13 in the development of these specifications. The Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns, submitted with this report by Committee D-13 to the Society for approval as a tentative standard, are nearly identical with those approved by the original committee at its meeting held in May, 1923.

The need for the development of Tentative Specifications for Tolerances and Test Methods for Sewing Threads was brought about by somewhat similar conditions to those outlined in the case of electrical yarns. The thread section of Sub-Committee VII on Yarn, Thread and Twine is growing very rapidly and it will probably be desirable in the near future to form a separate sub-committee of the concerns interested in threads.

The American Society for Testing Materials was requested by the Portland Cement Association to develop specifications and test methods for Osnaburg cement bags, and since these test methods should comply with the methods used for testing textiles, Committee D-13 was asked to organize a sub-committee for this work. At the meeting of Committee D-13 held in June, 1923, Sub-Committee X on Cement Bag Test Methods and Specifications, consisting, as mentioned above, of representatives of cement manufacturers, of cement bag manufacturers and of Osnaburg manufacturers, was organized to develop test methods and specifications for cement bags. After holding several meetings, this sub-committee, at the Spring meeting of Committee D-13, submitted the Specifications and Methods of Test for Osnaburg Cement Sacks appended hereto.

The present Tentative Specifications for Tolerances and Test Methods for Cotton Yarns and Cords have been revised to meet the demands of the trade for tolerance limits which will be acceptable to the consumer. The tolerances of the present specifications, particularly for yarn size, were so liberal that little attention was paid to them during the past year, resulting in a widespread demand for a general tightening. The new tolerances as presented are the result of considerable work by the sub-committee and are believed to be fair to both the manufacturer and the consumer. Special attention is called to the fact that the tolerances are based on average figures and on yarns which have been conditioned to standard moisture again.

The Special Sub-Committee on Membership has been very active in extending the membership of Committee D-13 which has resulted in strengthening the committee in the various fields of the textile industry to which the work of Committee D-13 applies. During the past year 35 new members have been enrolled.

The Special Sub-Committee on Publications has issued a pamphlet consisting of a compilation of all the standards, tentative standards, and important papers which have been presented by Committee D-13. This has been published in a large edition and has been very well received by the textile industry.

The recommendations contained in this report have been submitted to letter ballot of the committee, consisting of 93 members, with the following results:

Items	Affirmative	Negative	Not Voting
I. REVISION OF STANDARD			
Revision of Standard General Methods of Testing Cotton Fabrics (D 39 - 20)	51	2	12
II. REVISIONS OF TENTATIVE STANDARDS			
Tentative Specifications for Tolerances and Test Methods for Cotton Yarns and Cords (D 180 - 23 T)	46	4	15
Tentative Specifications and Tolerances for Hose Ducks and Belt Ducks (D 181 - 23 T)	42	0	23
III. NEW TENTATIVE STANDARDS			
Submission of Proposed Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns	42	3	21
Submission of Proposed Tentative Specifications for Tolerances and Test Methods for Cotton Sewing Threads	39	3	23
Submission of Proposed Tentative Specifications and Methods of Test for Osnaburg Cement Sacks	42	0	23

This report has been submitted to letter ballot of the committee, which consists of 93 members, of whom 59 have voted affirmatively, one negatively, and 43 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. E. JURY,
Chairman.

RUSSELL T. FISHER,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard General Methods of Testing Cotton Fabrics, proposed in 1923, were approved at the annual meeting, as recommended in this report, and were subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods, as revised, appear in the 1924 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Tolerances and Test Methods for Cotton Yarns and Cords and for Hose Ducks and Belt Ducks were approved, as recommended in this report. The tentative specifications, as thus revised, appear on pages 1063–1070.

The proposed Tentative Specifications for Tolerances and Test Methods for Electrical Cotton Yarns, for Cotton Sewing Threads and for Osnaburg Cement Sacks were accepted for publication as tentative, as recommended in this report, and appear on pages 1071–1080.

REPORT OF COMMITTEE D-15
ON
THERMOMETERS

During the past year, Committee D-15 has devoted its efforts to standardizing a number of the existing thermometer specifications of the Society, giving particular attention to the form of these specifications.

At the present time, there are two standard methods and two tentative methods of the Society, namely, the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 18), the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 18), the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products (D 86 – 23 T) and the Tentative Methods of Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water) (D 158 – 23 T) that call for thermometers that were originally supposed to be identical but which as they are at present written, differ slightly in unessential dimensions. These methods are under the jurisdiction of Committees D-2 on Petroleum Products and Lubricants, D-4 on Road and Paving Materials, and D-7 on Timber.

Committee D-15 has proposed two revised specifications to cover the requirements of these methods. It is proposed to call one of these "A.S.T.M. High-Distillation Thermometer, having a range of 0 to 400° C. or 30 to 760° F.," and the other "A.S.T.M. Low-Distillation Thermometer, having a range of 0 to 300° C. or 30 to 580° F." These specifications have been submitted to the respective committees for their approval.

It will be noted that Committee D-15 has recommended the inclusion of a footnote interpreting certain terms used in the thermometer specifications whose meaning in the past has been subject to considerable confusion.

The committee believes that the suggested interpretations will eliminate any confusion in the future between the manufacturers of thermometers and purchasers in connection with their inspection.

At the request of Committee D-2, Committee D-15 has revised the form but not the substance of four specifications for thermometers, as follows:

Test for Melting Point of Paraffin Wax (D 87 – 22);
Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T);
Test for Flash Point by Means of the Pensky-Martens Closed Tester (D 93 – 22);
Test for Cloud and Pour Points of Petroleum Products (D 97 – 23 T).

The committee believes that the specifications for the thermometer used for the melting point of paraffin wax (Method of Test D 87 – 22) could be improved by redesigning the thermometer so as to permit determining the ice point.

At the request of Committee D-4, Committee D-15 has suggested two specifications for thermometers to be used in softening point determinations, one having a range from 0 to 80° C. or 30 to 180° F. known as the "Low-Softening-Point Thermometer" and the other with a range of 30 to 160° C. or 85 to 320° F. to be known as the "High-Softening-Point Thermometer." These two thermometers will cover the requirements of the Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (D 36 – 21), the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 20) and the Tentative Method of Float Test for Bituminous Road Materials (D 139 – 23 T).

The thermometer for the distillation of turpentine according to the requirements of the Tentative Specifications for Turpentine (D 13 – 21 T) has been found quite difficult to manufacture owing to the very fine graduations that are required. The committee has been studying this question and expects to be in a position to recommend to Committee D-1 on Preservative Coatings for Structural Materials, which committee has jurisdiction over the specifications, a thermometer for trial that it is hoped will eliminate the difficulties met with in the present thermometer.

During the past year, the committee has held two of its meetings at the plants of thermometer manufacturers and it hopes to continue this practice. It is believed that in this manner, all of the members of the committee will secure a better understanding of the manufacturing requirements that will greatly aid the committee in its work on specifications.

The proposed specifications for thermometers have been approved by the committee and are appended hereto. They have been submitted to letter ballot of the committee with the following results:

Proposed Specifications	Affirmative	Negative	Not Voting
1. A.S.T.M. Thermometer for Cleveland Open Cup, 20 to 760° F.	10	0	2
2. A.S.T.M. Pensky-Martens High Flash Test Thermometer, 90 to 370° C. or 200 to 700° F	10	0	2
3. A.S.T.M. Cloud and Pour Test Thermometer, −38 to +50° C. or −36 to +120° F.	10	0	2
4. A.S.T.M. Pensky-Martens and Tag. Flash Test Thermometer, −5 to +110° C. or +20 to +230° F.	10	0	2
5. A.S.T.M. Low-Softening-Point Thermometer, 0 to 90° C. or 30 to 180° F.	10	0	2
6. A.S.T.M. High-Softening-Point Thermometer, 30 to 160° C. or 85 to 320° F.	10	0	2
7. A.S.T.M. Low-Distillation Thermometer, 0 to 300° C. or 30 to 580° F.	10	0	2
8. A.S.T.M. High-Distillation Thermometer, 0 to 400° C. or 30 to 760° F.	9	1	2
9. A.S.T.M. Paraffin Melting Point Thermometer, 25 to 70° C. or 80 to 160° F.	10	0	2

This report has been submitted to letter ballot of the committee, which consists of 12 members, of whom 10 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

E. F. MUELLER,
Secretary.

EDITORIAL NOTE

The proposed specifications for thermometers, appended to this report, have been incorporated in the standards under the jurisdiction of the various standing committees, as follows:

A.S.T.M. Thermometer for Cleveland Open Cup, incorporated in the Standard Method of Test for Flash and Fire Points by Means of Open Cup;

A.S.T.M. Pensky-Martens High Flash Test Thermometer, incorporated in the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester;

A.S.T.M. Cloud and Pour Test Thermometer, incorporated in the Tentative Method of Test for Cloud and Pour Points of Petroleum Products;

A.S.T.M. Pensky-Martens and Tag Flash Test Thermometer, incorporated in the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester and in the Method of Test for Flash Point of Volatile Flammable Liquids;

A.S.T.M. Low-Softening-Point Thermometer, incorporated in the Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method), the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) and in the Tentative Method of Float Test for Bituminous Materials;

A.S.T.M. High-Softening-Point Thermometer, incorporated in the Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method);

A.S.T.M. Low-Distillation Thermometer, incorporated in the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products;

A.S.T.M. High-Distillation Thermometer, incorporated in the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment, in the Standard Methods of Sampling and Analysis of Creosote Oil and in the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products;

A.S.T.M. Paraffin Melting Point Thermometer, incorporated in the Standard Method of Test for Melting Point of Paraffin Wax.

PROPOSED SPECIFICATIONS
FOR
A.S.T.M. THERMOMETER FOR CLEVELAND OPEN CUP, -6 to +400° C., +20 to +760° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −6 to +400° C. or +20 to +760° F., respectively.

2. The purpose of these specifications is to provide a thermometer for use with the Cleveland open cup.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: −6 to +400° C. in 2° C. or +20 to +760° F. in 5° F.

Total Length: 303 to 307 mm. (11.92 to 12.08 in.).

Stem: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, not over 13 mm. (0.51 in.).
Diameter, not greater than stem.

Distance to −6° C. or +20° F. Line from Bottom of Bulb: 40 to 50 mm. (1.57 to 1.97 in.).

Distance to 400° C. or 760° F. Line from Top of Thermometer: 30 to 45 mm. (1.18 to 1.77 in.).

Filling above Mercury: Nitrogen gas.

Top Finish: Red glass ring.

Graduation: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10° F. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20°.

Immersion: 25 mm. or one inch. The words "1-in. immersion" on Fahrenheit thermometers or "25-mm. immersion" on Centigrade thermometers and a line around the stem 25.4 mm. or 1.00 in. above the bottom of the bulb shall be etched on the thermometer.

Special Marking: "A.S.T.M. Open Flash" a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 1° C. up to 372° C. or 2½° F. up to 700° F.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 100° F. for 25-mm. or 1-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
100° C.	200° F.	44° C.	110° F.
150° C.	300° F.	54° C.	129° F.
200° C.	400° F.	64° C.	150° F.
250° C.	500° F.	77° C.	175° F.
300° C.	600° F.	91° C.	205° F.
350° C.	700° F.	108° C.	240° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 to 370° C. or 680 to 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Open Flash, −6 to +400° C." or "A.S.T.M. Open Flash, +20 to +760° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS

FOR

A.S.T.M. PENSKY-MARTENS HIGH FLASH TEST THERMOMETER, 90 to 370° C., 200 to 700° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 90 to 370° C. or 200 to 700° F., respectively.

2. The purpose of these specifications is to provide a thermometer suitable for use with the Pensky-Martens closed tester within these ranges.

3. The thermometer shall conform to the following requirements:

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 90 to 370° C. in 2° C. or 200 to 700° F. in 5° F.

TOTAL LENGTH: 273 to 277 mm. (10.75 to 10.92 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, not over 10 mm. (0.39 in.).
Diameter, not greater than stem.

DISTANCE TO 93° C. OR 200° F. LINE FROM BOTTOM OF BULB: 75 to 90 mm. (2.93 to 3.54 in.).

DISTANCE TO 371° C. OR 700° F. LINE FROM TOP OF THERMOMETER: 25 to 40 mm. (0.98 to 1.57 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10° C. or 25° F. line to be longer than the remaining lines. Graduations to be numbered at multiples of 20° C. or 50° F.

IMMERSION: 57 mm. or 2¼ in. The words "57-mm. immersion" on Centigrade thermometers or "2¼-in. immersion" on Fahrenheit thermometers and a line around the stem 57.0 mm. or 2.25 in. above the bottom of the bulb shall be etched on the thermometer.

SPECIAL MARKING: "A.S.T.M. P.M. High," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as described below shall not exceed 1° C. or 2½° F.

STANDARDIZATION: The thermometer shall be standardized at intervals of approximately 50° C. or 100° F. for 57-mm. or 2¼-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
100° C.	200° F.	61° C.	140° F.
150° C.	300° F.	65° C.	149° F.
200° C.	400° F.	71° C.	160° F.
250° C.	500° F.	78° C.	175° F.
300° C.	600° F.	87° C.	195° F.
350° C.	700° F.	99° C.	220° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 and 370° C. or 680 and 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. P.M. High, 90 to 370° C." or "A.S.T.M. P.M. High, 200 to 700° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS

FOR

A.S.T.M. CLOUD AND POUR TEST THERMOMETER, −38 to +50° C., −36 to +120° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −38 to +50° C. or −36 to +120° F., respectively.

2. The purpose of these specifications is to provide a thermometer suitable for use in the cloud and pour tests.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: −38 to +50° C. in 1° C. or −36 to +120° F. in 2° F.

Total Length: 220 to 224 mm. (8.69 to 8.81 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 7.0 to 8.0 mm. (0.28 to 0.31 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, not over 9.5 mm. (0.37 in.).
Diameter, not greater than stem.

Distance to −38° C. or −36° F. Line from Bottom of Bulb: 120 to 130 mm. (4.73 to 5.12 in.).

Distance to +49° C. or +120° F. Line from Top of Thermometer: 19 to 25 mm. (0.75 to 0.98 in.).

Expansion Chamber: To permit heating to 100° C. or 212° F.

Filling above Mercury: Nitrogen gas.

Top Finish: Plain.

Graduation: All lines, figures, and letters clear cut and distinct. Lines at multiples of 5° C. or 10° F. to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

Immersion: 108 mm. or 4¼ in.. The words "108-mm. immersion" on Centigrade thermometers or "4¼-in. immersion" on Fahrenheit thermometers and a line around the stem 108.0 mm. or 4.25 in. above the bottom of the bulb shall be etched on the thermometer.

Special Marking: "A.S.T.M. Cloud and Pour," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below, shall not exceed 0.5° C. or 1° F.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 20° C. or 40° F. for 108-mm. or 4¼-in. immersion and for an average temperature of 21° C. or 70° F. for the emergent mercury column.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Cloud and Pour, −38 to +50° C." or "A.S.T.M. Cloud and Pour, −36 to +120° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS
FOR
A.S.T.M. PENSKY-MARTENS AND TAG FLASH TEST THERMOMETER, −7 to +110° C., +20 to +230° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −7 to +110° C. or +20 to +230° F., respectively.

2. The purpose of these specifications is to provide a thermometer suitable for use with the Tag closed tester or with the Pensky-Martens closed tester within these ranges.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: −7 to +110° C. in 0.5° C. or +20 to +230° F. in 1° F.

Total Length: 273 to 277 mm. (10.75 to 10.92 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, 9 to 13 mm. (0.35 to 0.51 in.).
Diameter, not greater than stem.

Distance to −7° C. or +20° F. Line from Bottom of Bulb: 75 to 90 mm. (2.93 to 3.54 in.).

Distance to 110° C. or 230° F. Line from Top of Thermometer: 25 to 40 mm. (0.98 to 1.57 in.).

Expansion Chamber: To permit heating the thermometer at least 50° C. (90° F.) above highest temperature on scale.

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures, and letters clear cut and distinct. The whole degree Centigrade lines or the first and each succeeding 5° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 5° C. or 10° F.

Immersion: 57 mm. or $2\frac{1}{4}$ in. The words "57-mm. immersion" on Centigrade or "$2\frac{1}{4}$-in. immersion" on Fahrenheit thermometers and a line around the stem 57.0 mm. or 2.25 in. above the bottom of the bulb shall be etched on the thermometer.

Special Marking: "A.S.T.M. P.M. and Tag," a serial number and the manufacturer's name or trade mark, shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.5° C. or 1° F., respectively.

STANDARDIZATION: The thermometer shall be standardized at the ice point and at intervals of approximately 30° C. or 50° F. for 57-mm. or 2¼-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
20° C.	70° F.	20° C.	70° F.
40° C.	100° F.	31° C.	86° F.
70° C.	150° F.	40° C.	104° F.
100° C.	212° F.	48° C.	118° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. P.M. and Tag, −7 to +110° C." or "A.S.T.M. P.M. and Tag, +20 to +230° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS

FOR

A.S.T.M. LOW-SOFTENING-POINT THERMOMETER,
0 to 80° C., 30 to 180° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 0 to 80° C. or 30 to 180° F., respectively.

2. The purpose of these specifications is to provide a thermometer for float and softening point tests within these ranges.

3. The thermometer shall conform to the following requirements:

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −2 to +80° C. in 0.2° C. or +30 to +180° F. in 0.5° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 9 to 14 mm. (0.35 to 0.55 in.).
Diameter, 4.5 to 5.5 mm. (0.18 to 0.22 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 75 to 90 mm. (2.95 to 3.54 in.).

DISTANCE TO 80° C. OR 176° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

EXPANSION CHAMBER: To permit heating the thermometer at least 50° C. (90° F.) above highest temperature on scale.

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass Ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. Each whole degree Centigrade or Fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° C. or 5° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Low S.P.," a serial number and the manufacturer's name or trade mark shall be etched on the thermometer.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.2° C. or 0.4° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 20° C. or 40° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Low S.P., 0 to 80° C." or "A.S.T.M. Low S.P., 30 to 180° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS

FOR

A.S.T.M. HIGH-SOFTENING-POINT THERMOMETER, 30 to 160° C., 85 to 320° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 30 to 160° C. or 85 to 320° F., respectively.

2. The purpose of these specifications is to provide a thermometer suitable for softening point tests within these ranges.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: 30 to 160° C. in 0.5° C. or 85 to 320° F. in 1° F.

Total Length: 378 to 384 mm. (14.88 to 15.12 in.).

Stem: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, 9 to 14 mm. (0.35 to 0.55 in.).
Diameter, 4.5 to 5.5 mm. (0.18 to 0.22 in.).

Distance to 30° C. or 86° F. Line from Bottom of Bulb: 75 to 90 mm. (2.95 to 3.54 in.).

Distance to 160° C. or 320° F. Line from Top of Thermometer: 30 to 45 mm. (1.18 to 1.77 in.).

Expansion Chamber: To permit heating the thermometer at least 50° C. (90° F.) above the highest temperature on the scale.

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures, and letters clear cut and distinct. Each whole degree Centigrade line or the first and each succeeding 5° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 5° C. or 10° F.

Immersion: Total.

Special Marking: "A.S.T.M. High S.P.," a serial number and the manufacturer's name or trade mark shall be etched on the thermometer.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.3° C. or 0.5° F.

Standardization: The thermometer shall be standardized, immersed in the testing bath to the top of the mercury column, at intervals of approximately 40° C. or 70° F.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. High S.P., 30 to 160° C.," or "A.S.T.M. High S.P., 85 to 320° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS

FOR

A.S.T.M. LOW-DISTILLATION THERMOMETER,

0 to 300° C., 30 to 580° F.

1. These specifications cover a total immersion thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 0 to 300° C. or 30 to 580° F., respectively.

2. The purpose of these specifications is to provide a thermometer for distillation tests within these ranges.

3. The thermometer shall conform to the following requirements:

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 0 to 300° C. in 1° C. or 30 to 580° F. in 2° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 10 to 15 mm. (0.39 to 0.59 in.).
Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 100 to 110 mm. (3.94 to 4.33 in.).

DISTANCE TO 300° C. OR 572° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 5° C. or 10° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Low Distillation," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.5° C. or 1° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50° C. or 100° F. up to 300° C. or 572° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature of 280 to 290° C. or 540 to 560° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Low Distillation, 0 to 300° C." or "A.S.T.M. Low Distillation, 30 to 580° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS
FOR
A.S.T.M. HIGH-DISTILLATION THERMOMETER, 0 to 400° C., 30 to 760° F.

1. These specifications cover a total-immersion thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 0 to 400° C. or 30 to 760° F., respectively.

2. The purpose of these specifications is to provide a thermometer for distillation tests within these ranges.

3. The thermometer shall conform to the following requirements:

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 0 to 400° C. in 1° C. or 30 to 760° F. in 2° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 10 to 15 mm. (0.39 to 0.59 in.).
Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 25 to 35 mm. (0.98 to 1.38 in.).

DISTANCE TO 400° C. OR 752° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 5° C. or 10° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. High Distillation," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale up to 370° C. or 700° F. when the thermometer is standardized as provided below shall not exceed 1° C. or 2° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50° C. or 100° F. up to 370° C. or 700° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 and 370° C. or 680 and 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. High Distillation, 0 to 400° C." or "A.S.T.M. High Distillation, 30 to 760° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PROPOSED SPECIFICATIONS
FOR
A.S.T.M. PARAFFIN MELTING POINT THERMOMETER, 27 to 71° C., 80 to 160° F.

1. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 27 to 71° C., or 80 to 160° F., respectively.

2. The purpose of these specifications is to provide a thermometer suitable for determining the melting point of paraffin wax.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: 27 to 71° C. in 0.1° C. or 80 to 160° F. in 0.2° F.

Total Length: 365 to 371 mm. (14.38 to 14.56 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, not over 28 mm. (1.10 in.).
Diameter, not greater than stem.

Distance to 27° C. or 80° F. Line from Bottom of Bulb: 105 to 115 mm. (4.13 to 4.53 in.).

Distance to 71° C. or 160° F. Line from Top of Thermometer: 25 to 40 mm. (0.98 to 1.57 in.).

Contraction Chamber: Top to be not more than 41 mm. (1.61 in.) above bottom of bulb.

Expansion Chamber: To permit heating the thermometer to at least 100° C. (212° F.).

Filling above Mercury: Nitrogen gas.

Top Finish: Plain.

Graduation: All lines, figures, and letters clear cut and distinct. The first and each succeeding fifth line to be longer than the remaining lines. Graduations to be numbered at each 1° C. or each multiple of 2° F.

Immersion: 79 mm. or 3⅛ in. The words "79-mm. immersion" on Centigrade thermometers or "3⅛-in. immersion" on Fahrenheit thermometers and a line around the stem 79.0 mm. or 3.13 in. above the bottom of the bulb shall be etched on the stem.

Special Marking: "A.S.T.M. Pffe. M.P.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.1° C. or 0.2° F., respectively.

STANDARDIZATION: The thermometer shall be standardized at intervals of approximately 10° C. or 20° F. for 79-mm. or $3\frac{1}{8}$-in. immersion and for an average temperature of the emergent mercury column of 25° C. or 77° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Pffe. M.P., 27 to 71° C." or "A.S.T.M. Pffe. M.P., 80 to 160° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

REPORT OF COMMITTEE E-1

ON

METHODS OF TESTING

Committee E-1 on Methods of Testing has completed a year of considerable activity and is able to report substantial progress in a number of the projects upon which it is engaged.

As mentioned in previous reports, the committee has adopted a procedure, in principle, of studying methods from the broad viewpoint of the test as a type of test that may be made upon a wide variety of materials and comprising eventually the formulation of fundamental considerations that govern the various kinds of testing. Progress in the development of this program has been made this year in the preparation of Tentative Methods of Tension, Compression and Brinell Hardness Test of Metals and in the preparation of the proposed series of standard testing sieves, all of which are discussed later. At the same time the committee is endeavoring to pass as promptly as possible upon tentative methods of test as they are submitted by the standing committees. The committee will not withhold indefinitely approval of methods of test that standing committees may desire to see advanced to the status of standard, pending a study of the fundamental principles underlying the various kinds of tests involved in specific methods; but it does, however, reserve the privilege of reviewing methods thus advanced to standard and submitting criticism at some future time. Further reference is made to this feature of the committee's work.

One of the most important functions of Committee E-1 is to bring about helpful cooperation between standing committees developing similar methods of test, and the committee is able to report that in several instances it has been the means of bringing about such cooperation, which it is believed will eventually result in bringing forward methods of test mutually satisfactory to the cooperating committees.

As has previously been reported, the committee has classified the Society's methods of test into some sixteen groups, with the intention of developing this whole program along the lines suggested by this classification. The classification is given in Table I.

TABLE I.—CLASSIFICATION OF A.S.T.M. METHODS ACCORDING TO TYPE OF TEST.

- I. Mechanical Tests Made by Application of Stress-Producing Forces. (See also II.)
  - Tension.
  - Compression.
  - Crush.
  - Flattening.
  - Bend.
  - Fracture.
  - Homogeneity.
  - Flange.
  - Splitting.
  - Hydrostatic.
  - Brinell Hardness.
  - Shear.
  - Twist.
  - Impact.
  - Abrasion.
  - Friction.
  - Beading.
- II. Mechanical Tests Involving such Properties as Consistency, Plasticity, etc. (Closely related to I.)
  - Consistency.
  - Plasticity.
  - Viscosity.
  - Ductility.
  - Softening Point.
  - Melting Point.
  - Penetration.
- III. Tests for Density, Refractive Index, and Similar Physical Constants. (See also V in relation to Porosity.)
  - Density and Specific Gravity.
  - Unit Weight.
  - Refractive Index.
- IV. Classification of Material. (Including separation of materials, impurities, etc.)
  - Mechanical Separation.
  - Percentage of Waste.
  - Colorimetric Tests.
  - Determination of Foots.
  - Precipitation Number.
- V. Tests for Absorptive Properties. (See also III.)
- VI. Tests for Determination of Water.
- VII. Tests for Constancy of Volume.
- VIII. Tests for Time of Setting.
- IX. Thermal Tests.
  - (Cast-Iron Wheels.)
  - Chill Test.
  - Fire Test of Materials.
  - Freezing and Thawing.
  - Spalling Action.
  - Slagging Action.
  - Fusion.
  - Fusibility.
  - Cloud and Pour Tests.
  - Heating Test (Jellying of Tung Oil).
  - Dry Heat Test.
  - Digester Test.
- X. Test for Volatility.
  - Distillation.
  - Loss on Heating.
  - Flash and Fire Point.
- XI. Metallographic Tests.
- XII. Magnetic Tests.
- XIII. Dielectric Tests.
- XIV. Miscellaneous Tests of a Chemical Nature.
  - Free Carbon.
  - Soluble Bitumen.
  - Matter Insoluble in Benzol.
  - Alcohol Insoluble Matter.
  - Carbon Residue.
  - Determination of Ash.
  - Free Sulfur.
  - Discoloration of Copper.
  - Tinning Test.
  - Iodine Number.
  - Polymerization.
  - Determination of Acid.
  - Saponification Number.
  - Unsaponifiable Matter.
  - Strain Test.
  - Determination of Rosin.
  - Emulsification.
- XV. Color.
- XVI. Dimensional Measurements.
  - Measurements.
  - Crimp and Off-square.

Five sub-committees are at work on problems falling in as many groups, and a sixth Sub-Committee on Impact Testing has been organized as reported last year.

The committee has prepared a complete card index of the Society's standard and tentative methods of test, classified in accordance with the groups in Table I and adequately cross-referenced. This index has been of considerable use to the sub-committees and members of Committee E-1 in comparing the requirements of various methods, and copies of portions of it have been placed in the hands of the several sub-committee chairmen as an aid in studying the groups of methods assigned to them. It will be revised annually after each meeting of the Society, for the committee believes that it is important to maintain an up-to-date index of this character.

While the committee has necessarily devoted its major effort to the consideration of problems assigned to the sub-committees that have been organized, it has devoted such time as it could find to a general review of a number of miscellaneous methods of test (for example, tests of a chemical nature such as are indicated in group XIV of Table I) which for the most part involve only one standing committee and are usually of a more or less special nature as distinguished from the more general types of test. The desire of the committee in making such a review is simply to see that the requirements of these various methods are clearly and accurately stated, that no provisions are inconsistent with other methods of the Society, and finally that the form and arrangement of the methods are in accordance with the Society's requirements as given in the Regulations Governing the Form but not the Substance of Standards. This work, it is believed, will be essentially of an editorial nature, and the Advisory Committee, with the endorsement of Committee E-1, has created a committee of the Advisory Committee, consisting of three members and to be known as the Editorial Committee, which will be charged with the review of all such methods. The Editorial Committee will be empowered to communicate with the standing committees of the Society concerning any matters which seem to require clarification in these methods. The committee will report to the Advisory Committee, which will then determine what action should be recommended to Committee E-1. The Editorial Committee has been constituted as follows: C. L. Warwick, Chairman, F. G. Breyer, and W. H. Fulweiler.

Since the last report of the committee, the Sub-Committee on Classification of Material According to Size has been organized under the chairmanship of F. G. Breyer, a member of the Advisory Committee. Following is the personnel of this sub-committee:

F. G. Breyer, *Chairman*
R. E. Hess, *Secretary*

L. V. Judson (Bureau of Standards)
F. H. Jackson (Bureau of Public Roads)
H. S. Mattimore (Am. Assoc. State Highway Officials)
L. W. Walter (Committee C-1)
E. E. Eakins (Committee C-7)
D. A. Abrams (Committee C-9)
H. E. Brookby (Committee C-11)
R. L. Hallett (Committee D-1)
A. N. Johnson (Committee D-4)
F. P. Smith (Committee D-4)
A. C. Fieldner (Committee D-5)
W. B. Howard (Howard & Morse)

During the year, A. T. Goldbeck was obliged to resign the chairmanship of the Sub-Committee on Consistency, Plasticity, etc. The Advisory Committee accepted this resignation with regret and with an expression of its appreciation of Mr. Goldbeck's services, and has designated W. E. Emley to serve as chairman.

Since the last annual meeting, the Advisory Committee has held two meetings at the Society's headquarters, on November 16, 1923, and February 15, 1924. Committee E-1 has held one meeting, at the Society's headquarters on February 15, 1924.

GENERAL REVIEW OF COMMITTEE'S ACTIVITIES

The committee gives below a brief review of its work during the year, classified for convenience in accordance with the group headings of Table I. Reference should be made to the discussion in the last two annual reports of the work under these several groups.

I. Methods of Mechanical Tests Made by Application of Stress-Producing Forces.—For the present, this group is being developed only with respect to metals, by a sub-committee under the chairmanship of H. F. Moore, consisting of representatives of the several committees of the Society dealing with metals. Considerable progress has been made by this sub-committee and as a result of its work Committee E-1 is now prepared to recommend the withdrawal of the Society's Standard Methods of Mechanical Testing of Metallic Materials (E 1 – 18), which includes methods for tension, compression, transverse and Brinell hardness tests of metals, and the substitution therefor of the following:

Proposed Standard Methods of Verification of Testing Machines;

Proposed Tentative Methods of Tension Testing of Metallic Materials;

Proposed Tentative Methods of Compression Testing of Metallic Materials;

Proposed Tentative Methods of Brinell Hardness Testing of Metallic Materials;

Proposed Tentative Definitions of Terms Relating to Methods of Testing.

The work of this sub-committee is discussed in detail later in the report and the recommendations of the committee are there formally presented, with a brief discussion of the several methods of test that are being offered this year.

II. Methods of Mechanical Tests Involving Such Properties as Consistency, Plasticity, etc.—The sub-committee on this subject, under the chairmanship of W. E. Emley, has been studying the methods at present in use for measuring the "consistency" of fuel oils, lubricants, tar products, lime, cement, gypsum, concrete, magnesite, bituminous materials, and creosote residue. While this study has not yet been completed, and the sub-committee has held no meeting recently, it would seem that the methods used are merely different ways of applying the same principle. The methods are therefore fundamentally the same, although they vary so much physically that the results obtained from any two of them are not comparable.

As an expression of the above principle, the following definition is offered for criticism:

> *Consistency.*—The relation between the stress applied to a plastic body, the time during which it acts, and the deformation it produces.

III. Methods of Test for Density and Similar Physical Constants.—The principal tests in this group relate to the determination of density and specific gravity. Committee E-1 has deferred any consideration of the methods in the Society's standards and tentative standards for determining the properties classified in this group, pending the outcome of the work now being done by Committee E-8 on Nomenclature and Definitions in the preparation of fundamental definitions of "density" and "specific gravity." When agreement has been reached among the committees of the Society on such definitions, a review of the methods of test in this group will be made by Committee E-1.

IV. Methods of Classification of Material (Including Separation of Materials, Impurities, etc.).—The mechanical separation of materials, including grading and the determination of fineness, is the most important and widely used test in this group. During the year the organization of a sub-committee on this subject was completed, as mentioned earlier in the report, and the sub-committee has made excellent progress in its work. While fully recognizing the ultimate need for a more fundamental study of this subject, it was agreed that the immediate need is for some authoritative standard series of testing sieves and a recognized method of nomenclature so as to clear up the present confusion resulting from the existence of several different standards for sieves in the Society's specifications and elsewhere. The sub-committee has accordingly directed its efforts for the present to this specific problem and its recommendations are presented in detail later in the report.

V. Methods of Test for Absorptive Properties.—Some progress has been made in a review of the Society's methods for absorptive properties, and the tests in this group will be reviewed by the Editorial Committee.

VI. Methods of Test for Determination of Water.—As reported a year ago, the sub-committee on this group of tests, under the chairmanship of W. H. Fulweiler, was instrumental in harmonizing conflicting requirements in two methods of test for water submitted, respectively, by Committee D-2 on Petroleum Products and Lubricants and Committee D-4 on Road and Paving Materials. Through the efforts of this sub-committee, these two committees last year joined in recommending for publication as tentative the Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 23 T).[1] This method has stood as tentative for a year and this year Committees D-2 and D-4 are recommending its advancement to standard with a minor revision consisting in the addition of the following sentence to Section 9 on Procedure:

> "A loose cotton plug shall be inserted in the top of the condenser tube to prevent condensation of atmospheric moisture in the condenser tube."

This revision and the advancement of the revised method to standard has, on the recommendation of the sub-committee, been approved by formal letter ballot vote of Committee E-1 as follows: Advisory Committee, 5 affirmative, 0 negative, 3 not voting; Standing Committees, 14 affirmative, 0 negative, 21 not voting.

Another committee of the Society, Committee D-7 on Timber, is interested in this method of test in connection with analysis of creosote oil. The method is for the determination of water *per se*, which is of particular importance for the products studied by Committees D-2 and D-4, whereas in the case of creosote oil, such a determination is not an important factor. The Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 18) contain a method of dehydration, which is simply a step in the distillation of creosote oil and as such is a satisfactory method of determining the amount of water. The proposed method, which is applicable to creosote oil, involves the use of a solvent, which would render the sample unsuitable for the further test of distillation. Committee E-1 will, however, endeavor to secure the approval of Committee D-7 for the proposed method as a suitable one for determination of water *per se* in creosote oil.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 694 (1923).

This sub-committee is now turning its attention to other methods for the determination of water in various materials that fall within Group VI of the classification. These involve such products as turpentine, shellac and red lead, gypsum, coal and coke, and fabrics. A general statement is being prepared covering the basic principles of determination of water and moisture and an analysis of present methods in A.S.T.M. standards and tentative standards. This statement will be circulated among the members of the sub-committee for discussion during the coming year.

VII. Methods of Test for Constancy of Volume.

VIII. Methods of Test for Time of Setting.

IX. Methods of Thermal Tests.

Some progress has been made in a review of the Society's methods falling within these three groups, and these tests will be reviewed by the Editorial Committee.

X. Methods of Test for Volatility.—During the year this sub-committee, under the chairmanship of A. W. Dow, has reviewed the Tentative Method of Test for Flash and Fire Points by Means of Open Cup (D 92 – 23 T)[1] first submitted to the Society by Committee D-2 on Petroleum Products and Lubricants in 1921. Committee D-2 desires to recommend to the Society that this method be advanced to standard with a minor revision in which the first sentence of Section 2 is changed to read as follows:

> "The cup shall be supported on a metal plate ¼ in. (0.635 cm.) in thickness and 6 in. (15.24 cm.) in width."

This revision and the advancement of the revised method to standard is satisfactory to the sub-committee and on its recommendation has been approved by formal letter ballot vote of Committee E-1 as follows: Advisory Committee, 5 affirmative, 0 negative, 3 not voting; Standing Committees, 13 affirmative, 0 negative, 22 not voting.

The work of the sub-committee on methods of distillation in the several standards and tentative standards of the Society, reported upon last year, has been continued. One of the principal points of discussion is the use of the distillation flask and the distillation retort. Cooperative tests are shortly to be made by members of Committees D-2 on Petroleum Products and Lubricants, D-4 on Road and Paving Materials, and D-7 on Timber upon samples of tar and creosote which are to be distilled in the standard retort of Committee D-7 and in a modification of the standard distillation flask that is now under observation by members of these committees. The question of adoption of the modified flask in the distillation of gas oil is also being taken up with Committees D-2 and D-4. It is hoped that substantial progress in harmonizing the methods of distillation may be reported next year.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 690 (1923).

XI. Methods of Metallographic Tests.—The committee has delegated to Committee E-4 on Metallography the preparation of methods of metallographic tests. Tentative Methods of Metallographic Testing of Iron and Steel (E 3 – 23 T)[1] were submitted in 1921 and minor revisions were made last year. In 1923 the committee also submitted Tentative Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 23 T).[2] The form and arrangement of these methods have been reviewed and they have been found to be as nearly in concordance as possible with the regulations of the Society. Committee E-4 will propose this year that these two tentative methods be adopted as standard.

XII. Methods of Magnetic Tests.—In a similar way, methods of magnetic tests have been delegated to Committee A-6 on Magnetic Properties. Last year this committee proposed as tentative a revision of the Society's Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 18) in the form of a tentative standard.[3] These methods have also been reviewed as to form and are satisfactory from that viewpoint. Committee A-6 will recommend this year the adoption of the tentative methods as standard, to supersede the present standard methods.

XIII. Methods of Dielectric Tests.

XIV. Methods for Miscellaneous Tests of a Chemical Nature.

XV. Methods of Test for Color.

XVI. Methods for Certain Dimensional Measurements.

The tests in these four groups are for the most part highly specialized and the several tests are of interest to but one or two committees. Some progress has been made in a review of the methods falling within these four groups and they will be reviewed by the Editorial Committee.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 919 (1923).

[2] *Ibid.*, p. 931.

[3] *Ibid.*, p. 560.

TENTATIVE METHODS OF TEST

In addition to the classification of all methods of test as above discussed, Committee E-1 wishes to give consideration, in so far as it finds it possible, to the various tentative methods of test (as distinguished from standard methods) that are now published by the Society. In the 1923 publications there are 55 methods of test (exclusive of methods of chemical analysis). These are listed below by title, classified for convenience into three groups: Those first submitted in 1923; those first submitted in 1922; and those submitted prior to that date.

SUBMITTED BEFORE 1922

Tests for Compressive Strength of Cement Mortars, C 9 – 16 T

Slagging Action of Refractories, C 17 – 19 T

Resistance of Fire-Clay Brick to Spalling Action, C 38 – 21 T

Compression Tests of Concrete, C 39 – 21 T

Securing Specimens of Hardened Concrete, C 42 – 21 T

Specific Gravity of Road Oils and Tars, D 70 – 20 T

Specific Gravity of Asphalts and Tar Pitches, D 71 – 20 T

Clay in Sand-Clay, D 73 – 20 T

Distillation of Gasoline, etc., D 86 – 23 T

Viscosity of Petroleum Products, D 88 – 23 T

Sulfur in Naphthas, D 90 – 21 T

Precipitation Number of Lubricating Oils, D 91 – 21 T

*Flash and Fire Points by Open Cup, D 92 – 23 T

Saponification Number, D 94 – 21 T

SUBMITTED IN 1922

Sampling, Inspection, Packing and Marking of Quicklime, C 50 – 23 T

Melting Point of Petrolatum, D 127 – 22 T

Analysis of Grease, D 128 – 22 T

Sulfur in Heavy Petroleum Oils, D 129 – 22 T

Detection of Sulfur in Gasoline, D 130 – 22 T

Decantation Test for Sand, D 136 – 22 T

Mechanical Analysis of Subgrade Soils, D 137 – 23 T

Consistency of Concrete, D 138 – 22 T

Float Test for Bituminous Materials, D 139 – 23 T

Sampling Bituminous Materials, D 140 – 23 T

Testing Small Specimens of Timber, D 143 – 22 T

Testing Felted and Woven Fabrics for Use in Waterproofing, D 146 – 23 T

Testing Bituminous Mastics, D 147 – 23 T

Dielectric Strength of Sheet Insulating Mate-Trials, D 149 – 23

SUBMITTED IN 1923

*Magnetic Properties of Iron and Steel (A 34 – 23 T)

Determination of Bitumen (D 4 – 23 T)

*Testing Shellac (D 29 – 23 T)

*Specific Gravity of Pigments (D 153 – 23 T)

*Testing Oleo-Resinous Varnishes (D 154 – 23 T)

Color of Lubricating Oils (D 155 – 23 T)

Color of Refined Petroleum Oil (D 156 – 23 T)

Steam Emulsion of Lubricating Oils (D 157 – 23 T)

Testing Gas Oils (D 158 – 23 T)

Proportion of Bitumen Soluble in Carbon Tetrachloride (D 165 – 23 T)

*Volume of Cell Space of Lump Coke (D 167 – 23 T)

Coke Residue of Creosote Oil (D 168 – 23 T)

Electrical Insulating Materials for Voltage Effects at Radio Frequencies (D 175 – 23 T)

Testing Cable Splicing and Pothead Compounds (D 176 – 23 T)

SUBMITTED BEFORE 1922

*Water in Petroleum Products, D 95 – 23 T

*Water and Sediment in Petroleum Products, D 96 – 21 T

Cloud and Pour Points, D 97 – 23 T

Ductility of Bituminous Materials, D 113 – 22 T

Insulating Varnishes, D 115 – 23 T

Electrical Porcelain, D 116 – 21 T

Transformer and Switch Oils, D 117 – 21 T

*Metallographic Testing of Iron and Steel, E 3 – 23 T

SUBMITTED IN 1922

Phase Difference of Molded Electrical Insulating Materials, D 150 – 23 T

*Testing Rubber Products, D 15 – 23 T

Testing Cotton Fibers, D 152 – 22 T

SUBMITTED IN 1923

*Verification of Testing Machines (E 4 – 23 T)

*Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 23 T)

It has not been possible for Committee E-1 to study all of these methods, although a good deal has been done with some of them in studying certain general considerations and in reviewing their form and arrangement. (This review is a part of the routine editorial work in the Secretary-Treasurer's office and is now based upon the provisions respecting methods of test in the Regulations Governing the Form of Standards, originally proposed by Committee E-1.) As will be seen, some of these methods are special and of interest to only one or two committees of the Society and these will be studied as time permits by the Editorial Committee. The twelve methods marked with an asterisk are being recommended by the respective standing committees for advancement to standard this year. Formal approval of Committee E-1 has been recorded in connection with the advancement to standard of the following methods: D 92, D 95 and E 4, the latter being proposed by Committee E-1 itself. The committee has commented above with respect to the recommendations of Committees A-6 and E-4 in proposing that the following methods be advanced to standard: A 34, E 3 and E 5. With respect to the remaining six methods, namely, D 96, D 15, D 29, D 153, D 154 and D 167, the committee has not reviewed these as to their substance (although the form and arrangement is approved); but will interpose no objection to their advancement to the status of standard, reserving the privilege of submitting criticisms and recommendations at some later time when there has been opportunity to review them more carefully and in conjunction with similar methods. The Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 21 T) has not been reviewed at this time by the sub-committee handling group VI tests because it is essentially a practical test of sufficient accuracy for the purpose, prepared because of the desirability of standardizing this method as far as possible. It does not conflict in any way with the Method of Test for Determination of Water which has been approved by Committee E-1 and in fact contains the statement that "the accurate determination of water content, if desired, should be made in accordance with" the latter test.

REVISIONS OF STANDARD METHODS OF MECHANICAL TESTING OF METALLIC MATERIALS (E 1 – 18)

The sub-committee undertaking the revision of the Standard Methods of Mechanical Testing of Metallic Materials (E 1 – 18),[1] under the chairmanship of H. F. Moore, has made much progress during the past year. It held meetings at the Society's headquarters in November, 1923, and in February, 1924. Its recommendations were approved by Committee E-1 at the meeting in February, and the committee now presents them for action by the Society.

Withdrawal of Standard Methods of Mechanical Testing of Metallic Materials (E 1 – 18).—The progress made in the revision of the methods of tension, compression and Brinell hardness testing of metals is such that the committee believes the Standard Methods of Mechanical Testing of Metallic Materials should be withdrawn from the Book of Standards, with the understanding that they be replaced by the tentative methods for these tests recommended below. The Standard Methods include methods for transverse tests for which the committee has as yet no substitute to offer. The preparation of revised methods for transverse tests will be taken up next year.

The letter ballot vote of the committee on this recommendation is as follows: Advisory Committee, 6 affirmative, 0 negative, 2 not voting; Standing Committees, 15 affirmative, 0 negative, 20 not voting.

Methods of Verification of Testing Machines.—Last year the committee submitted Tentative Methods of Verification of Testing Machines (E 4 – 23 T)[2] which were accepted by the Society. These methods have been reviewed in the light of comments received and the committee has but one modification to make. It seemed desirable to clarify the section on method of procedure in which the pulling speed of the machine is specified for the Method of Verification by Comparison. Accordingly, it is proposed to change Section 12 (*b*) of the methods from its present form, namely,

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[1] 1921 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 911 (1923).

> "(*b*) The pulling speed of the movable head of the testing machine when testing verification specimens shall not exceed the speed of the movable head of the testing machine for determining the yield point of the material from which the specimens are made:[1] namely,

GAGE LENGTH, IN.	SPEED, IN PER MINUTE
2	0.50
8	2.00

> with proportional intermediate maximum speeds for gage lengths between 2 and 8 in."

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[1] A speed of 0.1 in. per minute would be still better, but would make the verification process a very slow one. The speed of head of the testing machine is the speed measured with the head running free with no specimen in the machine.

to read as follows:

> "(*b*) The speed of the testing machine, by which is meant the speed of the pulling head when the machine is running idle with no specimen in the machine, when testing verification specimens shall be approximately the same for both the standard testing machine and the machine being verified. The speed shall be the slowest speed that can be obtained on both machines; in any case the speed shall not exceed 1 in. per minute per inch of diameter of comparison specimen."

The committee recommends that the Tentative Methods of Verification of Testing Machines, as thus revised, be referred to letter ballot of the Society for adoption as standard. The letter ballot vote of the committee on this recommendation is as follows: Advisory Committee, 5 affirmative, 0 negative, 3 not voting; Standing Committees, 18 affirmative, 0 negative, 17 not voting.

One of the criticisms of these methods presented on the floor of the meeting last year related to the failure of the committee to include a method of verification by the use of the calibration bar. It was explained that the committee had not overlooked this method and intended to give it due consideration. During the year there has been prepared a Tentative Method of Verification of Testing Machines by Means of an Elastic Calibration Bar, which the committee appends hereto[1] with the recommendation that it be accepted by the Society for publication as tentative. The letter ballot vote of the committee on this recommendation is as follows: Advisory Committee, 6 affirmative, 0 negative, 2 not voting; Standing Committees, 18 affirmative, 0 negative, 17 not voting.

Methods of Tension Testing.—A year ago the committee submitted for information Suggested Methods of Tension Testing of Metallic

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[1] See p. 1106.—ED.

Materials, which were accepted for publication in the Proceedings.[1] These methods include requirements for test specimens, gripping devices, speed of operation of testing machines, and methods for the determination of elastic limit, yield point, tensile strength, elongation and reduction of area. A discussion on the plotting of stress-strain diagrams is also included. A number of suggestions and criticisms have been received and were taken carefully into consideration by the committee in reviewing the methods. Some revisions have been made, having to do principally with the clarification and amplification of the sections on test specimens. No revisions have been made in the specified speed of operation of the testing machine. It is required that the speed shall be such that the beam of the machine can be kept balanced and maximum limits are placed upon the speeds of testing for specimens of 2 and 8-in. gage length, with the statement that these maximum speeds represent the extreme of good laboratory practice for steel. An introductory note has been added to the methods making it clear that they deal simply with the form and dimensions, the machining and the testing of tension test specimens of metals, leaving such matters as methods of taking samples from which to prepare test specimens to be treated in the individual specifications. The revised Methods of Tension Testing of Metallic Materials are appended to this report[2] and the committee recommends that they be accepted for publication as tentative. The letter ballot vote of the committee on this recommendation is as follows: Advisory Committee, 6 affirmative, 1 negative, 1 not voting; Standing Committees, 15 affirmative, 1 negative, 19 not voting.

Methods of Compression Testing.—The committee has completely revised the Methods for Compression Testing of Metallic Materials given in the Standard Methods E 1 – 18. In so doing it has been guided largely by the experience of its members and of Committee B-2 on Non-Ferrous Metals and Alloys, which is the only metals committee in the Society that has included requirements for compression tests in its specifications. Information of value was also found in several technical papers presented to the Society in recent years. These methods, which are appended to this report,[3] comprise requirements for test specimens, bearing blocks, speed of testing machine, and methods of determining elastic limit, yield point and compressive strength. The committee recommends that they be accepted by the Society for publication as tentative. The letter ballot vote of the committee on this recommendation is as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 495 (1923).

[2] See p. 1081 —ED.

[3] See p. 1094.—ED.

Advisory Committee, 6 affirmative, 0 negative, 2 not voting; Standing Committees, 16 affirmative, 1 negative, 18 not voting.

Methods of Brinell Hardness Testing.—Similarly, the committee has completely revised the Methods for Brinell Hardness Tests that appear in the present Standard Methods E 1 – 18. These methods have been considerably extended and the revised methods are appended hereto.[1] They now cover in detail requirements for apparatus, test specimens, application and magnitude of load, methods of measuring the impression and requirements for the calibration of testing apparatus. A table of Brinell hardness numbers corresponding to various diameters of impression for loads of 500 and 3000 kg. has been included for convenience. In writing these methods the committee has had access to certain reports of the National Research Council Committee on Hardness and has consulted the report on Materials Testing of the Normenausschuss der Deutschen Industrie.

The committee recommends that these methods be accepted for publication as tentative. The letter ballot vote of the committee is as follows: Advisory Committee, 5 affirmative, 1 negative, 2 not voting; Standing Committees, 16 affirmative, 0 negative, 19 not voting.

Definitions of Terms Relating to Methods of Testing.—A year ago the committee submitted Definitions of Terms Relating to Methods of Testing (E 6 – 23 T)[2] which were accepted as tentative. These comprise definitions of the following terms:

Tension
Compression
Shear
Flexure
Torsion
Stress
Strain
Stress-Strain Diagram
Elastic Limit
Yield Point
Tensile Strength
Modulus of Elasticity

Accompanying the definitions of elastic limit and yield point are suggested methods for determining these properties, which have been embodied in the methods of tension and compression testing discussed above. The definitions have been subjected to a critical review both by the sub-committee in charge of them and by Committee E-8 on Nomenclature and Definitions, to which they were referred in accordance with regular Society procedure. As a result it has been determined to withdraw temporarily the definitions for tension, compression, shear, flexure, and torsion, which it was felt on further analysis were not sufficiently comprehensive, and the committee submits below as information definitions of these terms that have been proposed by Committee E-8 and which meet provisionally with the approval of the sub-committee:

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[1] See p. 1099.—Ed.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 937 (1923).

Tension.—The condition of elongation in some direction in a body or a portion of a body, resisted by components of balanced internal distributed forces in the same direction.

Compression.—The condition of shortening in some direction in a body or a portion of a body resisted by components of balanced internal distributed forces in the same direction.

Shear.—The condition of deformation resisted by balanced internal distributed forces, in which two contiguous parts of a body are shifted relatively to each other in a direction parallel to their plane of contact.

Flexure.—The condition of change of curvature of a body or a portion of a body resisted by balanced internal distributed forces having a resultant moment.

Torsion.—The condition of twist (relative rotation of two contiguous parts) about some axis in a body resisted by balanced internal distributed forces having a resultant moment.

Respecting the definitions of stress and strain the committee has made modifications which it thinks considerably improve them without altering the viewpoint from which definitions have been written. A slight modification in the definition of elastic limit has been made, the definition having been changed to read as follows by the omission of the words in brackets and the addition of the italicized words:

> "*Elastic Limit.*—The greatest stress which a material [can withstand] *is capable of withstanding* without *a permanent* deformation [which remains] *remaining* upon *complete* release of the [load] *stress.*"

No modification has been made in the definitions of yield point and modulus of elasticity. The definition of tensile strength, however, has been modified to read as follows by the omission of the words in brackets and the addition of the italicized words:

> "*Tensile Strength.*—The maximum *tensile* stress [carried by a test specimen in a tension test to rupture] *which a material is capable of withstanding.*"
>
> "*Note: In practice it is considered to be the maximum stress carried by a specimen representing the material in a tension test to rupture, under definite prescribed conditions.*"

The committee has also prepared the following definition of compressive strength:

> "*Compressive Strength.*—The maximum stress which a material that fails in compression by a shattering fracture is capable of withstanding."

The committee recommends that these definitions, as thus revised, be continued as tentative for another year. They are appended hereto[1] in their proposed revised form. The letter ballot vote of the committee is as follows: Advisory Committee, 6 affirmative, 0 negative, 2 not voting; Standing Committees, 19 affirmative, 1 negative, 15 not voting.

Additional Method for Determination of Elastic Limit.—The committee was asked when its report was presented last year to give some consideration to other methods for the determination of elastic limit. The committee has prepared a method of determining elastic limit by measurement of set after the application of a proof stress, a method that was used to a considerable extent during the war, particularly by British engineers. The method is applicable when it is desired to determine whether the elastic limit of a metal is above or below a specified stress. The method follows:

"A definite light initial stress is applied to the test specimen, and a gage line 2 in. long is laid off with a prick punch and a pair of dividers. The specified stress is then applied to the specimen, the specimen is held under this stress for at least five seconds, and the stress is then released to the initial value. If no set can be detected by the use of the dividers the elastic limit is reported as above the specified stress. An excellent surface for scribing with dividers may be produced by lightly plating the surface of the specimen with copper. For steel specimens this may be done by rubbing the specimen with a swab wet with an acidified solution of copper sulfate."

Discussion of this method in the committee brought out the fact that while it is a "logical" method for determining elastic limit, it calls for rather crude methods of measurement, that is, the use of dividers. The committee will welcome discussion of the method.

PROPOSED SERIES OF TESTING SIEVES[2]

The Sub-Committee on Classification of Material According to Size was authorized by Committee E-1 in 1921. The purpose of this sub-committee was to review all methods of test of the Society dealing with the separation of materials according to size, which is the most important test in group IV, Table I. Organization of the sub-committee was not effected, however, until the past year when the question of arriving at a standard sieve series was emphasized by the U. S. Bureau of Public Roads and an appeal made to Committee E-1 to see if this question, which causes considerable confusion in the problem of road building, could not be satisfactorily worked out. Accordingly, the sub-committee was formed to include representatives of interested A.S.T.M. committees, and representatives of the U. S. Bureau of Public Roads, the American Association of State Highway Officials and the U. S. Bureau of Standards, which has had considerable experience in the testing and standardization of sieves. The screen manufacturers were also invited to serve so as to give the committee the benefit of their advice on the practical considerations of screen manufacture. W. A. Howard, of Howard & Morse, accepted this invitation and accordingly is listed as a member of the sub-committee. The complete personnel is given earlier in the report. Mr. J. P. Hubbell acted for Mr. Breyer in the capacity of chairman, and the committee expresses its appreciation of his services.

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[1] See p. 1109.—ED.

[2] Although a distinction is made between "sieve" and "screen" in certain definitions of the Society and for certain purposes, the sub-committee has not yet agreed upon any recommended usage and the words are accordingly used synonymously in this report.

While the scope of the work of the sub-committee includes all methods of size testing, that of classification by means of sieves is the one of immediate importance. The committee accordingly decided at its organization meeting on November 15, 1923, to devote its attention to this phase of the classification of material as its first undertaking. In such classification two general types of screen are employed: perforated plates having circular openings and woven-wire screens having square or approximately square mesh. While screens with circular openings are to be recommended as offering fewer sources of error and giving a truer indication of the size of particle, from practical considerations it is necessary to use screens of woven wire, at least for the smaller sizes. The committee accordingly centered its attention on this type of screening device.

The method to be employed in designating sieves, whether by mesh (number of wires per inch), by arbitrary number, or by size of opening, was the first point of controversy. The decision was reached that probably the most practical designation would be by number, this number, however, referring to the size of opening only. In this way the Bureau of Standards' method of designation by numbers could be utilized, and it was felt there would be no difficulty in adapting screens at present in use to this method of designation. The further decision was reached to accept the Bureau's requirements for size of opening and nominal size of wire corresponding to these numbers as a basis for preparing a standard sieve series, although the Bureau's Standard Screen Scale could not be adopted in its entirety since there had been objection to the requirements for size of wire for screens of the finer openings. The important question to be settled was that of tolerances for opening and size of wire.

About this time the U. S. Bureau of Standards carried out an investigation to determine the effect of the size of wire upon the efficiency of a sieve. A similar investigation was conducted at the Structural Materials Research Laboratory of Lewis Institute.[1] These investigations supplied the necessary data so that at a subsequent meeting of the sub-committee held in February, 1924, it was found possible to approve a complete recommended series as given in Table II, with tolerances on opening and size of wire. The designations are based entirely on the screen opening and the tolerances on wire diameter are sufficiently broad so that the screens of recognized manufacturers having openings which fall within the limits of the series may meet the requirements. While the tolerances of wire diameter are considerably above those permitted by the U. S. Bureau of

TABLE II.—PROPOSED SERIES OF OPENINGS OF A.S.T.M. TESTING SIEVES WITH WIRE DIAMETERS AND TOLERANCES.

Opening Number	Sieve Opening		Wire Diameter		Tolerance in Average Opening, per cent	Tolerance in Wire Diameter, per cent		Tolerance in Maximum Opening, per cent
	mm.	in.	mm.	in.		Under	Over	
4	4.76	0.187	1.27	0.050	3	15	30	10
5	4.00	0.157	1.12	0.044	3	15	30	10
6	3.36	0.132	1.02	0.040	3	15	30	10
7	2.83	0.111	0.92	0.036	3	15	30	10
8	2.38	0.0937	0.84	0.0331	3	15	30	10
10	2.00	0.0787	0.76	0.0299	3	15	30	10
12	1.68	0.0661	0.69	0.0272	3	15	30	10
14	1.41	0.0555	0.61	0.0240	3	15	30	10
16	1.19	0.0469	0.54	0.0213	3	15	30	10
18	1.00	0.0394	0.48	0.0189	3	15	30	10
20	0.84	0.0331	0.42	0.0165	5	15	30	25
25	0.71	0.0280	0.37	0.0146	5	15	30	25
30	0.59	0.0232	0.33	0.0130	5	15	30	25
35	0.50	0.0107	0.29	0.0114	5	15	30	25
40	0.42	0.0165	0.25	0.0098	5	15	30	25
45	0.35	0.0138	0.22	0.0087	5	15	30	25
50	0.297	0.0117	0.188	0.0074	6	15	35	40
60	0.250	0.0098	0.162	0.0064	6	15	35	40
70	0.210	0.0083	0.140	0.0055	6	15	35	40
80	0.177	0.0070	0.119	0.0047	6	15	35	40
100	0.149	0.0059	0.102	0.0040	6	15	35	40
120	0.125	0.0049	0.086	0.0034	6	15	35	40
140	0.105	0.0041	0.074	0.0029	8	15	35	60
170	0.088	0.0035	0.063	0.0025	8	15	35	60
200	0.074	0.0029	0.053	0.0021	8	15	35	60
230	0.062	0.0024	0.046	0.0018	8	15	35	90
270	0.053	0.0021	0.041	0.0016	8	15	35	90
325	0.044	0.0017	0.036	0.0014	8	15	35	90

Screens having larger openings than those included in the table may be specified but in specifying screens of larger openings the actual size of the opening in inches or fractions of an inch shall be stated. A tolerance of 3 per cent on average openings and of 10 per cent on maximum openings shall be permitted.

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[1] These investigations are reported in two papers presented at the 1924 annual meeting of the Society, namely, "A Study of Sieve Specifications," by L. V. Judson, and "Influence of Diameter of Wire on Performance of Sieves," by D. A. Abrams. See *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II (1924).

Standards,[1] the results of the two investigations mentioned above indicated that these wide tolerances will not seriously affect the screening value, provided the openings are within the tolerance limit. It should, however, be pointed out that when wires are more than 15 per cent larger than the desired size, the screen may be somewhat less satisfactory from an operating point of view because it will probably take longer to reach the end point in a test with such screens.

The sub-committee submitted this proposed series to Committee E-1 at its meeting in February, at which the committee accepted it, and now presents it to the Society as a matter of information. The proposed series will be brought to the attention of the standing committees concerned for their critical review during the coming year. It will also be brought to the attention of the organizations represented on the sub-committee and of the screen manufacturers. In fact, the U. S. Bureau of Standards, on April 15, 1924, revised its standard sieve series to agree with that proposed by the committee.

In preparing the proposed requirements, the sub-committee wished to have at hand all existing requirements for testing sieves. An analysis was accordingly prepared, which included those specifications of the Society that had been formulated by the several standing committees, the requirements of the U. S. Bureau of Standards, and such requirements for testing sieves as could be obtained from catalogs of the several screen manufacturers. This analysis is set forth in Appendix II to this report. The proposed series has been included for comparison.

The sub-committee considered that a useful purpose would be served if it were to enumerate the points that should be considered in drawing up specifications for a sieving test. A list of such points is accordingly given in Appendix I to this report, and includes such matters as apparatus, sampling, preparation of samples, procedure, method of reporting, and allowable variations. In using this list as a basis for specifications, it is to be kept in mind that while due caution must be taken in each of the details of the sieving process, care must be used in writing any specification involving the sieving process that no refinement is incorporated therein unless for a definite purpose. For example, it is desirable to avoid the use of a series of sieves or of a complicated method of sieving if all the data and the precision desired may be obtained by the use of a single sieve by ordinary methods.

In discussing the essential features of sieve testing, the sub-committee was very much interested in a paper entitled "A Standard

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[1] This statement refers to the Bureau of Standards' requirements at the time this work was inaugurated, November, 1923. The requirements have since been revised as of April 15, 1924.

Sizing Test" prepared by Ernest A. Hersam for the consideration of the Committee on Milling Methods of the American Institute of Mining and Metallurgical Engineers, looking to the standardization of size testing. The paper has been issued in separate pamphlet form by the committee referred to. The outline appended agrees in general with the paper mentioned.

The question of round-hole screens is still under consideration. The sub-committee believes that both the square and round openings should be permitted, but that round openings are to be preferred for any new line of investigation where considerable data have not already been accumulated on the basis of the square-mesh sieve. There is now a sub-committee of Committee D-5 on Coal and Coke that is carefully studying the question of specifications for round-hole screens. As soon as the results of this study are available, Committee E-1 will determine on the proper tolerance in diameter of hole, thickness of plate, and requirements for spacing and finishing the holes.

IMPACT TESTING

The Sub-Committee on Impact Testing, under the chairmanship of E. B. Smith, has made some progress in the study of impact tests along the lines announced in the report last year. The chairman is preparing for submission to the sub-committee an outline for a series of tests in which it is hoped to show the value of the Charpy and Izod test on notched bars, the aim being to determine whether the method of comparison is proper. Plans are also being made for an investigation on the elastic properties of materials (concrete in particular) under impact loads.

An analysis in detail is being made in the Secretary-Treasurer's office of the practice with respect to notched impact tests of metals as revealed in the Symposium on Impact Testing of Materials,[1] with the object of seeing if it is possible to recommend standard specimens and methods for making these tests.

This report has been submitted to letter ballot of the committee with the following result: Advisory Committee, 7 affirmative, 0 negative, 1 not voting; total, 8; Standing Committees, 27 affirmative, 0 negative, 8 not voting; total, 35.

Respectfully submitted on behalf of the committee,

J. A. CAPP,
Chairman.

C. L. WARWICK,
Ex-Officio Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part II, p. 5 (1922).

EDITORIAL NOTE

The Tentative Methods of Verification of Testing Machines, revised as recommended in this report, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The methods appear in the 1924 Book of A.S.T.M. Standards.

The revisions of the Tentative Definitions of Terms Relating to Methods of Testing, recommended in this report, were approved. The tentative definitions, as thus revised, appear on page 1109. The proposed Tentative Method of Verification of Testing Machines by Means of an Elastic Calibration Bar, the proposed Methods of Tension Testing of Metallic Materials, of Compression Testing of Metallic Materials and of Brinell Hardness Testing of Metallic Materials were accepted for publication as tentative, as recommended in this report, and appear on pages 1081–1108.

The withdrawal of the Standard Methods of Mechanical Testing of Metallic Materials, recommended in this report, was approved.

APPENDIX I

LIST OF POINTS TO BE CONSIDERED IN DRAWING UP SPECIFICATIONS FOR A SIEVING TEST

I. APPARATUS.

1. Enumeration of sieves by standard number. (These may be selected from series proposed by the sub-committee; see p. 18).
2. Auxiliary apparatus required for collection and reduction of gross sample, sample containers, and apparatus other than the sieves used in making the tests.

II. SAMPLING.

1. Unit of Sampling.
2. Method of collecting representative gross sample.
3. Size of gross sample.
4. Cautions to be taken in handling sample to prevent contamination or change.
5. Reduction of gross sample.

III. PREPARATION OF THE SAMPLE FOR TESTING.

1. Drying.
2. Mixing.
3. Special treatment, if any is necessary.
4. Selection of test portion.
5. Size of test portion.

IV. PROCEDURE.

A. Dry Screening:

1. Order in which the sieves are to be used.
2. Detailed description of method of shaking.
3. Detailed description of procedure other than method of shaking.
4. End point.

B. Wet Screening:

1. Liquid to be used.
2. Description of any preliminary separation by classification or other means.
3. Order in which screens are to be used.
4. Detailed description of procedure including amount and method of adding liquid, method of stirring or other agitation.
5. End point.

V. METHOD OF REPORTING RESULTS.

VI. ALLOWABLE VARIATIONS BETWEEN DUPLICATE TESTS ON THE SAME MATERIAL.

APPENDIX II

COMPARISON OF SPECIFICATIONS AND DIMENSIONS OF TESTING SIEVES

Number, Mesh, or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
3 in.	A.S.T.M. C 41	3.00	0.25	3 per cent	10 per cent	10 per cent
2 in.	A.S.T.M. C 41	2.00	0.192	3 per cent	10 per cent	10 per cent
1½ in.	A.S.T.M. C 41	1.50	0.177	3 per cent	10 per cent	10 per cent
1 in.	A.S.T.M. C 41	1.00	0.162	3 per cent	10 per cent	10 per cent
	Tyler	1.050	0.149	....	...	...
¾ in.	A.S.T.M. C 41	0.75	0.135	3 per cent	10 per cent	10 per cent
	Tyler	0.742	0.135	....	....	....
2 (½ in.)	A.S.T.M. C 41	....	....	....	....	....
	Ludlow-Saylor	0.437	0.063	....	....	....
	Tyler	0.525	0.105	....	....	....
2½ (⅜ in.)	A.S.T.M. C 41	0.375	0.092	3 per cent	10 per cent	10 per cent
	Bureau of Standards	0.315	0.073	1.5 “	10 “	10 “
	Ludlow-Saylor	....	....	....	....	....
	Tyler	0.371	0.092	....	....	....
3	A.S.T.M. C 41	....	....	....	....	....
	Bureau of Standards	0.265	0.065	1.5 per cent	10 per cent	10 per cent
	Ludlow-Saylor	0.279	0.054	....	....	....
	Newark Wire Cloth	0.279	0.054	....	....	....
	Tyler	0.263	0.070	....	....	....
3½	A.S.T.M. C 41	....	....	....	....	.... 10 per cent
	Bureau of Standards	0.223	0.057	1.5 per cent	10 per cent	....
	Ludlow-Saylor	....	....	....	....	....
	Newark Wire Cloth	....	....	....	....	....
	Tyler	....	....	....	....	....
4	A.S.T.M. C 41	0.187	0.050	3 per cent	10 per cent	10 per cent
	Bureau of Standards	0.187	0.050	1.5 “	10 “	10 “
	**Revised Bureau of Standards*	*0.187*	*0.050*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.201	0.049	....	....	....
	Ludlow-Saylor	0.203	0.047	....	....	....
	Newark Wire Cloth	0.203	0.047	....	....	....
	Tyler	0.185	0.065	....	....	....
	PROPOSED SERIES	**0.187**	**0.050**	3 per cent	10 per cent	**15 per cent under** **30 “ over** (0.042 – 0.065 in)
5	A.S.T.M. C 41	....	....	....	....	....
	Bureau of Standards	0.157	0.044	1.5 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.157*	*0.044*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	....	....	....	....	....
	Ludlow-Saylor	0.159	0.041	....	....	....
	Newark Wire Cloth	0.159	0.041	....	....	....
	Tyler	....	....	....	....	....
	PROPOSED SERIES	**0.157**	**0.044**	3 per cent	10 per cent	**15 per cent under** **30 “ over** (0.037 – 0.057 in.)
6	A.S.T.M. C 41	....	....	....	....	....
	Bureau of Standards	0.132	0.040	1.5 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.132*	*0.040*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.131	0.035	....	....	....
	Ludlow-Saylor	0.132	0.035	....	....	....
	Newark Wire Cloth	0.132	0.035	....	....	....
	Tyler	0.131	0.036	....	....	....
	PROPOSED SERIES	**0.132**	**0.040**	3 per cent	10 per cent	**15 per cent under** **30 “ over** (0.034 – 0.052 in.)

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COMPARISON OF SPECIFICATIONS AND DIMENSIONS OF TESTING SIEVES—*(Continued)*

Number, Mesh, or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
7	A.S.T.M. C 41	....	....	....	....	....
	Bureau of Standards	0.111	0.036	1.5 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.111*	*0.036*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	....	....	....	....	....
	Ludlow-Saylor	....	....	....	....	....
	Tyler	....	....	....	....	....
	PROPOSED SERIES	**0.111**	**0.036**	3 per cent	10 per cent	15 per cent under 30 “ over (0.031 - 0.047 in.)
8	A.S.T.M. C 41	0.0937	0.0331	3 per cent	10 per cent	10 per cent
	Bureau of Standards	0.0937	0.0331	3 “	10 “	10 “
	**Revised Bureau of Standards*	*0.0937*	*0.0331*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.0955	0.0295	....	....	....
	Ludlow-Saylor	0.097	0.028	....	....	....
	Newark Wire Cloth	0.097	0.028	....	....	....
	Tyler	0.093	0.032	....	....	....
	PROPOSED SERIES	**0.0937**	**0.0331**	3 per cent	10 per cent	15 per cent under 30 “ over (0.0282–0.0429 in.)
10	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	0.079	0.022	0.1 mesh	....	0.002 in.
	Bureau of Standards	0.0787	0.0299	3 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0787*	*0.0299*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.073	0.027	....	....	....
	Ludlow-Saylor	0.075	0.025	....	....	....
	Newark Wire Cloth	0.075	0.025	....	....	....
	Tyler[1]	....	....	....	....	....
	PROPOSED SERIES	**0.0787**	**0.0299**	3 per cent	10 per cent	15 per cent under 30 “ over (0.0254 - 0.0389 in.)
12	A.S.T.M. C 41	....	....	....	....	..
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0661	0.0272	3 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0661*	*0.0272*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.0583	0.025	....	....	....
	Ludlow-Saylor	0.060	0.023	....	....	....
	Newark Wire Cloth	0.060	0.023	....	....	....
	Tyler[1]	0.065	0.035	....	....	....
	PROPOSED SERIES	**0.0661**	**0.0272**	3 per cent	10 per cent	15 per cent under 30 “ over (0.0231 - 0.0353 in.)
14	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0555	0.0240	3 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0555*	*0.0240*	*3 “*	*10 “*	*15 per cent under* *30 “ over*
	Howard & Morse	0.0485	0.023	....	....	....
	Ludlow-Saylor	0.051	0.020	....	....	....
	Newark Wire Cloth	0.051	0.020	....	....	....
	Tyler[2]	....	....	....	....	....
	PROPOSED SERIES	**0.0555**	**0.0240**	3 per cent	10 per cent	15 per cent under 30 “ over (0.0204 - 0.0312 in.)

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[1] This sieve, listed by Tyler as 10 mesh, has an opening corresponding to No. 12 and has been grouped accordingly.

[2] This sieve, listed by Tyler as 14 mesh, has an opening corresponding to No. 16 and has been grouped accordingly.

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COMPARISON OF SPECIFICATIONS AND DIMENSION OF TESTING SIEVES—(*Continued*)

Number, Mesh, or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
16....	A.S.T.M. C 41	0.0469	0.0213	3 per cent	10 per cent	10 per cent
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0469	0.0213	3 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0469*	*0.0213*	*3 "*	*10 "*	*15 per cent under* *30 " over*
	Howard & Morse	0.0420	0.0205	....	....	....
	Ludlow-Saylor	0.0445	0.018	....	....	....
	Newark Wire Cloth	0.0445	0.018	....	....	....
	Tyler[1]	0.046	0.025	....	....	....
	Proposed Series	**0.0469**	**0.0213**	3 per cent	10 per cent	15 per cent under 30 " over (0.0181-0.0277 in.)
18....	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0394	0.0189	3 per cent	10 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0394*	*0.0189*	*3 "*	*10 "*	*15 per cent under* *30 " over*
	Howard & Morse	0.0368	0.01875	....	....	....
	Ludlow-Saylor	0.0386	0.017	....	....	....
	Newark Wire Cloth	0.0386	0.017	....	....	....
	Tyler	....	....	....	....	....
	Proposed Series	**0.0394**	**0.0189**	3 per cent	10 per cent	15 per cent under 30 " over (0.0161-0.0246 in.)
20....	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	0.0335	0.0157	0.5 mesh	....	0.0006 in.
	Bureau of Standards	0.0331	0.0165	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0331*	*0.0165*	*5 "*	*25 "*	*15 per cent under* *30 " over*
	Howard & Morse	0.0335	0.0165	....	....	....
	Ludlow-Saylor	0.0340	0.016	....	....	....
	Newark Wire Cloth	0.0340	0.016	....	....	....
	Tyler	0.0328	0.0172	....	....	....
	Proposed Series	**0.0331**	**0.0165**	5 per cent	25 per cent	15 per cent under 30 " over (0.0140-0.0215 in.)
22....	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	....	....	....	....	....
	Ludlow-Saylor	0.0305	0.015	....	....	....
	Newark Wire Cloth	....	....	....	....	....
	Tyler	....	....	....	....	....
25 (24)...	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0280	0.0146	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0280*	*0.0146*	*5 "*	*25 "*	*15 per cent under* *30 " over*
	Howard & Morse	0.02795	0.01375	....	....	....
	Ludlow-Saylor	0.0277	0.014	....	....	....
	Newark Wire Cloth	0 0277	0.014	....	....	....
	Tyler	....	....	....	....	....
	Proposed Series	**0.0280**	**0.0146**	5 per cent	25 per cent	15 per cent under 30 " over (0.0124-0.0189 in.)
30 (28)...	A.S.T.M. C 41	0.0232	0.0130	4 per cent	25 per cent	10 per cent
	A.S.T.M. D 7	0.0197	0.0130	1.0 mesh	....	0.0005 in.
	Bureau of Standards	0.0232	0.0130	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0232*	*0.0130*	*5 "*	*25 "*	*15 per cent under* *30 " over*
	Howard & Morse	0.02108	0.01225	....	....	....
	Ludlow-Saylor	0.0205	0.0128	....	....	....
	Newark Wire Cloth	0.0203	0.013	....	....	....
	Tyler	0.0232	0.0125	....	....	....
	Proposed Series	**0.0232**	**0.0130**	5 per cent	25 per cent	15 per cent under 30 " over (0.0110-0.0169 in.)

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[1] This sieve, listed by Tyler as 14 mesh, has an opening corresponding to No. 16 and has been grouped accordingly.

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COMPARISON OF SPECIFICATIONS AND DIMENSIONS OF TESTING SIEVES—(*Continued*).

Number, Mesh or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
35	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0197	0.0114	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0197*	*0.0114*	*5 "*	*25*	*15 per cent under 30 " over*
	Howard & Morse	0.01732	0.01125	....	....	....
	Ludlow-Saylor	0.0168	0.0118	....	....	....
	Newark Wire Cloth	0.0176	0.011	....	....	....
	Tyler	0.0164	0.0122	....	....	....
	PROPOSED SERIES	**0.0197**	**0.0114**	**5** per cent	**25** per cent	**15** per cent under **30** " over (0.0097–0.0148 in.)
40	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	0.0142	0.0102	1.5 mesh	....	0.0004 in.
	Bureau of Standards	0.0165	0.0098	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0165*	*0.0098*	*5 "*	*25 "*	*15 per cent under 30 " over*
	Howard & Morse	0.01475	0.01025	....	....	....
	Ludlow-Saylor	0.0146	0.0104	....	....	....
	Newark Wire Cloth	0.015	0.010	....	....	....
	Tyler	....	....	....	....	....
	PROPOSED SERIES	**0.0165**	**0.0098**	**5** per cent	**25** per cent	**15** per cent under **30** " over (0.0083–0.0127 in.)
45	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0138	0.0087	4.5 per cent	25 per cent	10 per cent
	**Revised Bureau of Standards*	*0.0138*	*0.0087*	*5 "*	*25 "*	*15 per cent under 30 " over*
	Howard & Morse	....	....	....	....	....
	Ludlow-Saylor	0.0127	0.0095	....	....	....
	Newark Wire Cloth	0.0127	0.0095	....	....	....
	Tyler	....	....	....	....	....
	PROPOSED SERIES	**0.0138**	**0.0087**	**5** per cent	**25** per cent	**15** per cent under **30** " over (0.0074–0.0113 in.)
50 (48)	A.S.T.M. C 41	0.0117	0.0074	6 per cent	40 per cent	20 per cent
	A.S.T.M. D 7	0.0114	0.0083	2 mesh	....	0.0004 in.
	Bureau of Standards	0.0117	0.0074	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0117*	*0.0074*	*6 "*	*40 "*	*15 per cent under 35 " over*
	Howard & Morse	0.011	0.009	....	....	....
	Ludlow-Saylor	0.0110	0.0090	....	....	....
	Newark Wire Cloth	0.0110	0.009	....	....	....
	Tyler	0.0116	0.0092	....	....	....
	PROPOSED SERIES	**0.0117**	**0.0074**	**6** per cent	**40** per cent	**15** per cent under **35** " over (0.0063–0.0100 in.)
60	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0098	0.0064	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0098*	*0.0064*	*6 "*	*40 "*	*15 per cent under 35 " over*
	Howard & Morse	0.009	0.0075	....	....	....
	Ludlow-Saylor	0.0092	0.0075	....	....	....
	Newark Wire Cloth	0.0092	0.0075	....	....	....
	Tyler	....	....	....	....	....
	PROPOSED SERIES	**0.0098**	**0.0064**	**6** per cent	**40** per cent	**15** per cent under **35** " over (0.0054 –0.0086 in.)
70 (65)	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0083	0.0055	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0083*	*0.0055*	*6 "*	*40 "*	*15 per cent under 35 " over*
	Howard & Morse	0.0078	0.0065	....	....	....
	Ludlow-Saylor	0.0073	0.0070	....	....	....
	Newark Wire Cloth	0.0073	0.007	....	....	....
	Tyler	0.0082	0.0072	....	....	....
	PROPOSED SERIES	**0.0083**	**0.0055**	**6** per cent	**40** per cent	**15** per cent under **35** " over (0.0047–0.0074 in.)

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COMPARISON OF SPECIFICATIONS AND DIMENSIONS OF TESTING SIEVES—(*Continued*).

Number, Mesh, or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
80...	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	0.0067	0.0059	3 mesh	....	0.0003 in.
	Bureau of Standards	0.0070	0.0047	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0070*	*0.0047*	*6* "	*40* "	*15 per cent under* *35* " *over*
	Howard & Morse	0.00675	0.00575	....	....	....
	Ludlow-Saylor	0.0070	0.0055	....	....	....
	Newark Wire Cloth	0.0068	0.00575	....	....	....
	Tyler	0.0069	0.0056	....	....	....
	Proposed Series	**0.0070**	**0.0047**	**6 per cent**	**40 per cent**	**15 per cent under** **35 " over** **(0.0040–0.0635 in.)**
90...	A.S.T.M. C 41	....	....	....	....	....
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.006	0.005	....	....	....
	Ludlow-Saylor	0.0063	0 0048	....	....	....
	Newark Wire Cloth	0.0061	0.005	....	....	....
	Tyler	....	....	....	....	....
100...	A.S.T.M. C 41	0.0059	0.0040	6 per cent	40 per cent	20 per cent
	A.S.T.M. D 7	0.0055	0.0046	3 mesh	....	0.0003 in.
	Bureau of Standards	0.0059	0.0040	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0059*	*0.0040*	*6* "	*40* "	*15 per cent under* *35* " *over*
	Howard & Morse	0.0055	0.0045	....	....	....
	Ludlow-Saylor	0.0056	0.0044	....	....	....
	Newark Wire Cloth	0.0055	0.0045	....	....	....
	Tyler	0.0058	0.0042	....	....	....
	Proposed Series	**0.0059**	**0.0040**	**6 per cent**	**40 per cent**	**15 per cent under** **35 " over** **(0.0034–0.0054 in.)**
110...	A.S.T.M. C 41	(Specification C 41 has no requirements for sieves above 100.)				
	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.005	0.004	....	....	....
	Ludlow-Saylor	0.00509	0.0040	....	....	....
	Newark Wire Cloth	0.0051	0.004	....	....	....
	Tyler	....	....	....	....	....
120 (115)..	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0049	0.0034	6 per cent	40 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0049*	*0.0034*	*6* "	*40* "	*15 per cent under* *35* " *over*
	Howard & Morse	0.0046	0.0036	....	....	....
	Ludlow-Saylor	0.00463	0.0037	....	....	....
	Newark Wire Cloth	0.0046	0.0037	....	....	....
	Tyler	0.0049	0.0038	....	....	....
	Proposed Series	**0.0049**	**0.0034**	**6 per cent**	**40 per cent**	**15 per cent under** **35 " over** **(0.0029 – 0.0046 in.)**
130...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.0041	0.0036	....	....	....
	Ludlow-Saylor	0.00439	0.0033	....	....	....
	Newark Wire Cloth	0.0043	0.0034	....	....	....
	Tyler	....	....	....	....	....
140...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0041	0.0029	7.5 per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0041*	*0.0029*	*8* "	*60* "	*15 per cent under* *35* " *over*
	Howard & Morse	0.0039	0.0032	....	....	....
	Ludlow-Saylor	0.00424	0.0029	....	....	....
	Newark Wire Cloth	0.0042	0.0029	....	....	....
	Tyler	....	....	....	....	....
	Proposed Series	**0.0041**	**0.0029**	**8 per cent**	**60 per cent**	**15 per cent under** **35 " over** **(0.0025 –0.0039 in.)**

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* The revised series of the U. S. Bureau of Standards is the same as the Proposed Series prepared by the subcommittee. It has been adopted by the Bureau as of April 15, 1924.

COMPARISON OF SPECIFICATIONS AND DEFINITIONS OF TESTING SIEVES—(*Continued*).

Number, Mesh, or Size	Specification	Sieve Opening, in.	Wire Diameter, in.	Tolerance		
				Average Opening	Maximum Opening	Wire Diameter
150...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.0036	0.003	....	....	....
	Ludlow-Saylor	(No requirements for sieves above 140.)				
	Newark Wire Cloth	0.0041	0.0026	....	....	....
	Tyler	0.0041	0.0026	....	....	....
160...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.00345	0.0028	....	....	....
	Newark Wire Cloth	0.0038	0.0025	....	....	....
	Tyler	....	....	....	....	....
170...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	0.0035	0.0025	7½ per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0035*	*0.0025*	*8 "*	*60 "*	*15 per cent under* *35 " over*
	Howard & Morse	0.0033	0.0026	....	....	....
	Newark Wire Cloth	0.0035	0.0024	....	....	....
	Tyler	0.0035	0.0024	....	....	....
	PROPOSED SERIES	**0.0035**	**0.0025**	**8 per cent**	**60 per cent**	**15 per cent under** **35 " over** (0.0021 – 0.0034 in.)
180...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.0031	0.0024	....	....	....
	Newark Wire Cloth	0.0033	0.0023	....	....	....
	Tyler	....	....	....	....	....
190...	A.S.T.M. D 7	....	....	....	....	....
	Bureau of Standards	....	....	....	....	....
	Howard & Morse	0.0031	0.0022	....	....	....
	Newark Wire Cloth	....	....	....	....	....
	Tyler	....	....	....	....	....
200...	A.S.T.M. D 7	0.0029	0.0021	8 mesh	....	0.0002 in.
	Bureau of Standards	0.0029	0.0021	7½ per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0029*	*0.0021*	*8 "*	*60 "*	*15 per cent under* *35 " over*
	Howard & Morse	0.0028	0.0022	....	....	....
	Newark Wire Cloth	0.0029	0.0021	....	....	....
	Tyler	0.0029	0.0021	....	....	....
	PROPOSED SERIES	**0.0029**	**0.0021**	**8 per cent**	**60 per cent**	**15 per cent under** **35 " over** (0.0018 - 0.0028 in.)
230...	A.S.T.M. D 7	(Specification D 7 has no requirements for sieves above 300.)				
	Bureau of Standards	0.0024	0.0018	7½ per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0024*	*0.0018*	*8 "*	*90 "*	*15 per cent under* *35 " over*
	Howard & Morse	(No requirements for sieves above 200.)				
	Newark Wire Cloth	0.0025	0.018	....	....	....
	Tyler	(No requirements for sieves above 200.)				
	PROPOSED SERIES	**0.0024**	**0.0018**	**8 per cent**	**90 per cent**	**15 per cent under** **35 " over** (0.0015–0.0024 in.)
270...	Bureau of Standards	0.0021	0.0016	7½ per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0021*	*0.0016*	*8 "*	*90 "*	*15 per cent under* *35 " over*
	Newark Wire Cloth	0.0021	0.0016	....	....	....
	PROPOSED SERIES	**0.0021**	**0.0016**	**8 per cent**	**90 per cent**	**15 per cent under** **35 " over** (0.0014–0.0022 in.)
325...	Bureau of Standards	0.0017	0.0014	7½ per cent	60 per cent	20 per cent
	**Revised Bureau of Standards*	*0.0017*	*0.0014*	*8 "*	*90 "*	*15 per cent under* *35 " over*
	Newark Wire Cloth	0.0017	0.0014	....	....	....
	PROPOSED SERIES	**0.0017**	**0.0014**	**8 per cent**	**90 per cent**	**15 per cent under** **35 " over** (0.0012 - 0.0019 in.)

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*The revised series of the U. S. Bureau of Standards is the same as the Proposed Series prepared by the subcommittee. It has been adopted by the Bureau as of April 15, 1924.

DISCUSSION

Mr. Knerr.

MR. H. C. KNERR.[1]—Referring to the additional method for determining elastic limit, as given on page 712 of the report, the proposed method does not determine the elastic limit but merely determines whether it has been exceeded. It is a proof test.

Referring to the proposed Definitions of Terms Relating to Methods of Testing, submitted as information on page 711 of the report, tension is defined as a "condition of elongation," etc. It would seem that the condition of elongation is only a result of the tension and depends upon the modulus of elasticity of the material in question. The same tension in two materials, such as steel and aluminum, will produce different "conditions of elongation." Is not tension a force tending to increase the length of a body or the distance between the points at which it is applied, or else the equal and opposite reacting force within the body?

Similar comments would apply to definitions for compression, shear, flexure and torsion.

In the Tentative Definitions of Terms Relating to Methods of Testing[2] it would seem that, to conform with testing practice "stress" should be defined in terms of load divided by original area of cross-section. This is, of course, not the true stress from a physicist's standpoint. This distinction between true stress and nominal stress might well be made clear.

It is suggested that a definition of the term "proportional limit" be included.

Method I for determining elastic limit, as given in Section 17 of the Tentative Methods of Tension Testing of Metallic Materials,[3] is really a test for determining proportional limit (although the words "a sudden increase" would make the method inapplicable to many materials in which the increase in rate of elongation is not sudden). Why not say so, and then state that the elastic limit may in most cases be assumed to coincide with the proportional limit? (This is not always true, if results reported in Mr. McAdam's recent papers are correct.)

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[1] Metallurgist, Naval Aircraft Factory, Navy Yard, Philadelphia, Pa.

[2] See p. 1109.—ED.

[3] See p. 1081.—ED.

Mr. Knerr. Referring to Method II for determining yield point, as given in Section 18 of these methods,[1] the question may be raised, "What is visible stretch?" Compare proof test for determining elastic limit on page 712 of the report. If the amount of set or of stretch which is visible to the observer is the same in both cases, the yield point will be reported less than the elastic limit, for in the method for determining yield point the elastic deformation will be included in the stretch which the observer is able to detect, whereas in the proof test for elastic limit it is not included.

Fig. 1 of these methods, which represents the specimens used in testing sheet material, is not suitable for thin sheet, that is, material less than about $\frac{1}{4}$ in. in thickness. There seems to be need for another specimen for testing thin sheet. It is suggested that the radius of shoulder shown in Fig. 2 be changed to read "not less than diameter of the gage section." Since tolerances on width of gage section are shown in Figs. 2 and 3, tolerances might well be considered for Fig. 1.

Fig. 7 of the methods shows a gripping device for thin material. Attention is invited to self-adjusting grips described by N. S. Otey in *Iron Age* for April 3, 1924, which have proved even more satisfactory for general use than those shown in Fig. 7.

The methods proposed for measuring elongation under Notes 2 and 3 of Section 20 of the methods would not be suitable for metals which do not neck down and which elongate uniformly along the gage length, such as some grades of bronze, for example.

Mr. Vanick. MR. J. S. VANICK.[2]—The following comment is offered concerning the suggested dimensions for compression specimens, as set forth in Section 4 of the Tentative Methods of Compression Testing of Metallic Materials.[3] Except for the short specimen, the reasons for the dimensions chosen are not clear. Unless there is some objection not stated in the report it would seem to the writer to be good judgment to use $1\frac{1}{8}$ in. for the diameter of all three specimens, instead of using 1 in. for the medium-length specimen and $1\frac{1}{4}$ in. for the long specimen. The remaining length multiples of the diameter might remain as presented.

Mr. Marshall. MR. C. H. MARSHALL.[4]—Fig. 1 of the proposed Tentative Methods of Compression Testing of Metallic Materials[3] shows the proportions of the three classes of compression specimens, and sug-

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[1] See p. 1081.—ED.

[2] Metallurgist, International Nickel Co., Elizabeth, N. J.

[3] See p. 1094.—ED.

[4] Testing Engineer, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

Mr. Marshall.

gested values for dimensions are given. For short specimens of soft materials the dimensions seem satisfactory and tests of such specimens might be expected to give results which are comparable with those given by tests on 1-in. cubes, which are frequently used.

For the medium-length specimen a diameter of 1 in. is suggested. With a specimen of this size for steel with a strength greater than 125,000 lb. per sq. in. the 1-in. specimen would be beyond the capacity of a 100,000-lb. testing machine. Moreover, several commercial extensometers can not take in a 1-in. specimen. For many years the laboratories of the Westinghouse Electric and Manufacturing Co. have been using a compression test specimen 0.798 in. in diameter (area of cross-section very nearly ½ sq. in.) and 2½ in. high. This specimen permits the use of the common Ewing 2-in. extensometer and the accurate determination of elastic limit and modulus of elasticity. This specimen has proved to be well suited to the compression testing of all materials from the softest Babbitt to the hardest steel. All these materials fail under loads which can be read conveniently on a 150,000-lb. testing machine. The ratio of diameter to length is such that the specimen fails along its natural angle, and yet there is no trouble from bending action.

For the proposed long specimen the ratio of diameter to length is 1 to 10. At about this ratio a material will begin to act as a column, that is, the specimen may fail by bending rather than by compression. The only reason given for using the long specimen is that it is a good specimen to use for determining the modulus of elasticity, but the diameter and length proposed prohibits the use of most extensometers which are made to be used with a 2-in. gage length. By the use of an extensometer like the Ewing the elastic limit and modulus of elasticity can be very accurately determined. Why, therefore, use a larger and longer specimen for this purpose?

Section 8 of the methods states that a spherical-seated bearing block is required for a compression test. The writer believes that such a block should be recommended, but not required. If the ends of the cylinder under test are parallel and the plates between which it is compressed are also parallel the spherical bearing is obviously unnecessary.

No definition has been given in the methods for the ultimate compressive strength of metals and alloys which crush down in compression without fracturing. Many of the softer metals and alloys act in this way and it is very important that the ultimate compressive strength of such metals should be defined in some way. In the Westinghouse laboratories hundreds of compression tests on, perhaps, fifty different soft alloys have been made and the following method of determining a value designated, as compressive strength has proved very satisfactory: The stress which corresponds to 10 per cent shortening in height is taken as the compressive strength for metals which do not fracture before they reach that percentage of shortening.

Mr. Petrenko.

MR. S. N. PETRENKO.[1]—Recent experiments at the Bureau of Standards indicate that the proposed requirements for balls for Brinell hardness tests are more severe than can be met in practice, and the following modification of Section 2 of the Tentative Methods of Brinell Hardness Testing of Metallic Materials[2] is suggested:

> "(*a*) A ball to be suitable for use shall not show a permanent change in diameter greater than 0.0025 mm. (0.0001 in.) when pressed with a force of 3000 kg. (6614 lb.) against a steel plate having a Brinell hardness number of 350 ± 25.
>
> "(*b*) If a ball is to be used in a test of a specimen having a Brinell hardness number greater than 350, the ball shall first be tested on a steel plate having a Brinell hardness number of 600 ± 25. If the permanent change in the diameter of the ball is less than 0.015 mm. (0.0006 in.) it may be used on metals having a Brinell hardness number greater than 350, using the undeformed portion of the ball to make the impression.
>
> "(*c*) If more than one impression is to be made on a material of greater hardness than Brinell 350, the same portion of the ball is to be used to make each impression.
>
> "(*d*) No ball shall be used in testing harder material after it has been used for testing material having a Brinell hardness of 350 or greater."

Mr. Templin.

MR. R. L. TEMPLIN.[3]—Several points in connection with the proposed Tentative Methods of Tension Testing of Metallic Materials[4] seem to be worthy of comment.

Under Method II for the determination of yield point, as given in Section 18, it may be pointed out that in the testing of heat-treated high-strength aluminum alloys in the wrought condition quite an appreciable amount of elongation may occur between gage marks on the specimen before the yield point of the material is actually reached. When such a metal is tested using an 8-in. gage length it can be readily seen that the total elongation in 8 in. at a stress of 40,000 lb. per sq. in. is in excess of 0.032 in. As total extensions of 0.01 in. are readily visible it is evident that in attempting to use Method II for the determination of yield point of such material quite low values of this mechanical property would be obtained.

The use of a strainometer and the arbitrary deformation value

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[1] Associate Mechanical Engineer, U. S. Bureau of Standards, Washington, D. C.

[2] See p. 1099.—ED.

[3] Chief Engineer of Tests, Aluminum Co. of America, New Kensington, Pa.

[4] See p. 1081.—ED.

Mr. Templin.

of 0.01 in. over a gage length of 2 in. will give much better results on the material just mentioned. If this material, however, be appreciably cold-worked after heat treatment so as to give a tensile strength in the neighborhood of 70,000 lb. per sq. in., the use of the arbitrary value of 0.01 in. for the deformation over a gage length of 2 in. will give yield point values appreciably less than those actually obtained. With the modulus of elasticity 10,000,000 lb. per sq. in. and the deformation 0.5 per cent, we obtain an indicated stress of 50,000 lb. per sq. in. while alloy 17S-T[1] cold-worked after heat treatment may, and often does, have a yield point appreciably in excess of 50,000 lb. per sq. in.

In Section 13 of the methods as well as in Section 10 of the Tentative Methods of Compression Testing of Metallic Materials,[2] the requirement appears that "Deviations from parallelism should not exceed 0.01 in. The movable head of the machine should be free from sidewise motion that is visible to the unaided eye as the machine is run at its fastest speed." The first of these statements appears rather ambiguous because the distance to be traversed before the limiting value of deviation of 0.01 in. is reached is not stated. The second statement regarding the allowable sidewise motion of the movable head of the testing machine is likewise rather indefinite but perhaps it is intentionally so.

In Section 7 (*b*) of the Tentative Methods of Brinell Hardness Testing of Metallic Materials[3] I should like to point out that the time of application of load (30 seconds) is quite inadequate for making hardness tests on magnesium and on alloys whose major constituent is magnesium. For such metals the minimum time of load application should be 2 minutes.

Mr. Breyer.

MR. F. G. BREYER.[4]—In the Tentative Methods of Brinell Hardness Testing of Metallic Materials[3] the recommendation for test specimens reads: "The thickness of the piece tested shall be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the impression."

It has been the experience in the laboratories of the New Jersey Zinc Co. that in testing very soft non-ferrous metals there is a decided reinforcement or backing up by the anvil under the test specimen, although in many cases no bulge or marking can be seen on the underside of the test specimen. We are not alone in this experience as

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[1] An aluminum-copper alloy.

[2] See p. 1094.—ED.

[3] See p. 1099.—ED.

[4] Chief, Research Division, New Jersey Zinc Co., Palmerton, Pa.

Mr. Breyer. Mr. de Forest reports similar findings in the testing of brass.[1] His recommendation, which we have found to be very satisfactory in our own testing work, was that the test specimen should have a thickness of at least ten times the depth of the impression.

TABLE I.—RESULTS OF TESTS ON NON-FERROUS METALS TO SHOW THE EFFECT OF SPEED OF TESTING.

Material	Testing Speed, in. per min.	Tensile Strength, lb. per sq. in.	Difference, lb. per sq. in.
Copper "Dead Soft" Annealed	0.27	32 300	
		32 300	
		Aver. 32 300	
	2.08	32 800	
		32 600	
		Aver. 32 700	400
Copper, Two "Numbers" Hard	0.27	35 200	
		35 200	
		Aver. 35 200	
	2.08	36 000	
		36 000	
		Aver. 36 000	800
Copper, Four "Numbers" Hard	0.27	41 500	
		41 000	
		Aver. 41 300	
	2.08	41 000	
		42 200	
		Aver. 41 600	300
Copper Spring Temper	0.27	62 000	
		60 500	
		Aver. 61 300	
	2.08	62 600	
		62 000	
		Aver. 62 300	1000
Aluminum "Soft" Annealed	0.27	13 500	
		12 800	
		Aver. 13 200	
	2.08	13 000	
		12 900	
		Aver. 13 000	200
Aluminum "¼ Hard"	0.27	18 900	
		18 900	
		Aver. 18 900	
	2.08	20 600	
		20 600	
		Aver. 20 600	1700
Aluminum "½ Hard"	0.27	23 600	
		23 600	
		Aver. 23 600	
	2.08	26 400	
		25 900	
		Aver. 26 200	2600
Aluminum "¾ Hard"	0.27	33 200	
		34 000	
		Aver. 33 600	
	2.08	35 500	
		34 200	
		Aver. 34 900	1300
Rolled Zinc 0.055 in. Thick	0.023	23 500	....
	0.150	28 500	5000
	0.500	30 800	2300
	1.50	37 200	6400
	3.00	38 700	1500

The committee's recommendation concerning the application and magnitude of load reads: "The load shall be applied for at least 10 seconds in the case of iron and steel and at least 30 seconds in the case of other metals." We believe it would be more advisable, in testing of non-ferrous metals, to set a definite time, say, 30, 40 or 50 seconds for maintaining the load. In testing pure zinc and soft non-ferrous alloys we find that our hardness results are dependent

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XVIII, Part II, p. 466 (1918).

Mr. Breyer.

upon the length of time the load is maintained, even when the duration of the load is greater than 30 seconds.

Referring to the Tentative Methods of Tension Testing of Metallic Materials,[1] we believe that the testing speeds given in Section 14, although representing good laboratory practice for steel, may not necessarily represent good practice for non-ferrous metals. Would it not be better to fix definite testing speeds (with permissible variations) which represent good average testing speeds for non-ferrous metals? As I interpret these directions, most non-ferrous metals would fall in the class of 80,000 lb. (or under), in which case the material could be tested for tensile strength at any testing speed up to 2 in. per minute for a 2-in. gage length. We know definitely that appreciable variations in tensile strength can be secured within this range with a number of non-ferrous metals in strip or sheet form. To illustrate this point, we have made some tension tests on specimens of strip-rolled aluminum and copper in various hardnesses, all 0.021 in. thick, and some rolled zinc 0.055 in. thick. The test section was milled out to give a 2-in. gage length with a generous fillet at each end. The results are given in Table I. While there are one or two contradictions in this tabulation, in general it bears out our criticism.

Mr. H. F. Moore.

MR. H. F. MOORE[2] (*Chairman of Sub-Committee on Mechanical Testing of Metallic Materials*).—In formulating tentative definitions of elastic limit, yield point, tensile strength, and modulus of elasticity the Sub-Committee on Mechanical Testing of Metallic Materials has attempted always to formulate a definition of a property of a material, not a definition of a method of determining that property. In defining elastic limit this distinction is especially noteworthy. Sometimes elastic limit and proportional limit are given separate definitions depending on the method used in determining the limit. To the sub-committee there seemed no appreciable difference in physical significance between the two, each is the stress at the beginning of appreciable inelastic action. Methods of making this determination may differ in detail and in accuracy, but the significant thing determined is a property of the material, not the mere result of a method of test. An accurate determination of elastic limit by direct measurement of set necessitates a stress-set diagram. The mere indication of a small set at one reading of the extensometer is not reliable in determining elastic limit unless under succeeding larger loads the set increases systematically.

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[1] See p. 1081.—ED.

[2] Professor of Engineering Materials, University of Illinois, Urbana, Ill.

Mr. H. F. Moore. The writer is rather surprised that Mr. Marshall has trouble using strainometers on a specimen 1 in. in diameter, as the writer has frequently used a short-length Ewing extensometer on a specimen of that size.

The writer would also point out that the fact that a specimen with a length 10 times its diameter may fail as a column does not make it useless for the determination of modulus of elasticity, which is determined not at failure but at stresses below the elastic limit. In the opinion of the writer, even with a Ewing extensometer, accurate values of the modulus of elasticity cannot be obtained by means of measurements over a 2-in. gage length; a gage length at least 8 in. long should be used, and many 8-in. extensometers are on the market, including an 8-in. Ewing extensometer.

The writer also feels that a spherical-seated bearing should be required for compression tests, not only on account of the imperfections in machining specimens but even more on account of the slight lack of parallelism always found in the heads of testing machines.

The suggestions of Mr. Petrenko are well worth very careful consideration. The test data on which they were based were not available to the sub-committee when their report was prepared.

The criticism by Mr. Breyer on the lack of a tabulation of allowable testing speeds for non-ferrous metals is pertinent, but so far the sub-committee has not been able to formulate such a table. It is not certain that one such tabulation would cover the entire non-ferrous field.

Mr. R. R. Moore. MR. R. R. MOORE[1] (*by letter*).—In regard to the proposed Tentative Methods of Tension Testing of Metallic Materials,[2] Method I for determining the elastic limit does not appear to be satisfactory for any great variety of metals. It is applicable only to those metals whose stress-strain curve breaks more or less sharply at the elastic limit so that the "sudden increase" in rate of elongation is quite evident. A great many metals, however, do not register this sharp break but bear away gradually from the straight line giving a shallow flat curve. With such a material it is impossible to locate the elastic limit by the "sudden increase" in rate of elongation because it does not exist any more than a yield point exists for these metals. The rate of increase is often so gradual that the observer cannot detect it until after considerable stretch has taken place and the elastic limit has been greatly exceeded. The metals belonging to this class which

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[1] Chief, Physical Testing Branch, Engineering Division, U. S. Air Service, McCook Field, Dayton, Ohio.

[2] See p. 1081.—ED.

Mr. R. R. Moore.

have come under the writer's observation are the heat-treated steels, bronzes, and light alloys, especially the light cast alloys. It seems to me that if this method is to be recommended in a general specification, some statement should be made as to the class of materials to which it applies, or a warning given that it may fail to work satisfactorily in all cases.

Method II, of course, overcomes the difficulties just mentioned. The selection of 50 per cent as the increase in rate of deformation is quite arbitrary. This would be too great for a large number of alloys. A value of 25 per cent would give values nearer to the actual elastic limit which I think is preferable.

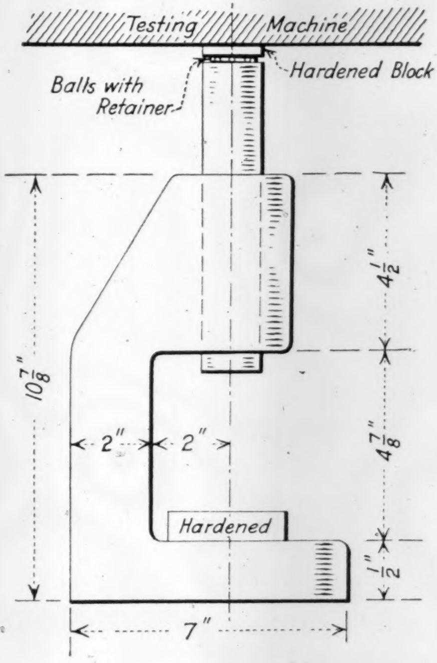

FIG. 1.—Compression Tool.

I notice that no mention is made of what I would call the "inspection," or more specifically the "graphical inspection" method, which is to plot the curve and select the "break" by inspection. We have used this method considerably and although it is open to criticism, due to discrepancies between the selections of different observers, I do not consider that these differences are greater than the differences you will find in several test specimens of the same material. The

Mr. R. R. Moore. results obtained by both Methods I and II are affected by the class of material, while the "inspection" method is affected only in so far that it is more difficult to make a selection from a very flat curve. Method I, however, is out of the question on materials with flat curves, and Method II gives values too high. It seems to me that the "inspection" method is also one of the "methods in common use" and is also the more general method.

In Fig. 6, the steel ball is given as $\frac{5}{8}$ in. in diameter. The breaking load of this ball is about 35,000 lb. per sq. in., which would correspond to a tensile strength of about 175,000 lb. per sq. in. on a 0.505-in. specimen. This apparatus, therefore, could not be used on a large variety of heat-treated alloy steels.

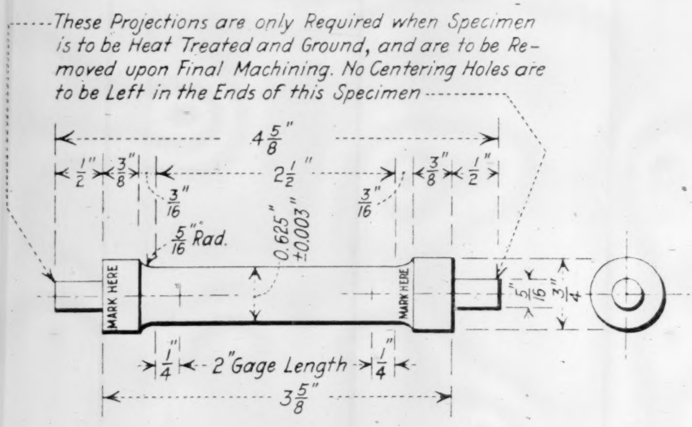
These Projections are only Required when Specimen is to be Heat Treated and Ground, and are to be Removed upon Final Machining. No Centering Holes are to be Left in the Ends of this Specimen

FIG. 2.—Compression Test Specimen.

Referring to the proposed Tentative Methods of Compression Testing,[1] I should like to suggest a method of eliminating the effect on the test specimen of the rocking or weaving of the testing machine head, a matter which we have found to be very troublesome. The making of an accurate compression test, especially if strain readings are to be taken, is extremely difficult owing to the care which must be taken to insure axial and uniformly distributed loading. I think it will be conceded that the screw type of testing machine as most commonly used in this country becomes subject to these ills after some use. The effect of such action on a compression specimen is disastrous, but can be avoided by applying the load to the specimen through a plunger held in a solid frame. The specimen is set on the base of

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[1] See p. 1094.—ED.

Mr. R. R. Moore.

this frame so that there is no relative lateral motion between the specimen and the point of application of the load, which would of course tend to bend it. A sketch of such a tool is shown in the accompanying Fig 1. This tool was formerly used to make crushing tests on balls. For the specific purpose of compression tests of metals, some refinements might be introduced.

The test specimen which we used is shown in Fig 2. We have found this to be quite satisfactory. Strain readings are taken over a 2-in. gage length with a Berry strain gage which, of course, reads backwards when used in compression. With such a set-up the proportional limit and tensile strength of the ductile metals check very well with these values in tension. The strain readings are not quite reliable enough for accurate modulus values with this type of extensometer and gage length. The compressive strength is computed from the maximum load which the specimen takes. The failure on the steels will occur by buckling. This value, however, checks very close with the tensile strength.

[For discussion on the yield point of white metals in compression, see the discussion of the Report of Committee B-2 on Non-Ferrous Metals and Alloys, page 275.—ED.]

REPORT OF COMMITTEE E-4
ON
METALLOGRAPHY

Two meetings of Committee E-4 were held during the year, one at Atlantic City, June 25, 1923, and another at Pittsburgh, March 12, 1924.

Mr. H. C. Boynton has been elected chairman, and Mr. G. F. Comstock has been re-elected secretary.

Sub-Committee I on Selection and Preparation of Samples reports progress and calls attention to a method of drying specimens without the use of alcohol as follows:

> After etching, wash in very hot water and dry in an air-blast. With this method the results obtained are as good as with the older method of using alcohol after washing in water. After etching with dilute nitric acid solutions, steels in the unhardened condition do not show the stains which generally appear after drying with alcohol.

The sub-committee also submits a critical Bibliography of Etching prepared by William Campbell to be used in connection with the Tentative Methods E 3 – 23 T and E 5 – 23 T. It is appended hereto.

The Tentative Definitions of Terms Relating to Metallography (E 2 – 23 T)[1] have been given further consideration during the year. A number of revisions have been made, such as the deletion of the definition for the term "Equi-axed," the inclusion of the substance of the definition for "Muntz-Metal" as a note under "Beta Brass," and a complete revision of the definitions for the term "alloy."

The definitions in their revised form are appended hereto.[2] They have been submitted to Committee E-8 on Nomenclature and Definitions for approval. The committee recommends the adoption of the Tentative Definitions of Terms as corrected as standard to be published as a separate standard, not as a part of Definitions E 2 – 20 as stated last year.

The committee discussed the suggestion that the term "Metallographic Testing," which occurs in the titles of two of its methods, included the photographing of specimens. The committee is unanimously of the opinion that photography should not be considered as a part of metallographic testing but rather as a means of making a record of the test.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 943 (1923).

[2] See 1924 Book of A.S.T.M. Standards.—Ed.

The Sub-Committee on Thermal Analysis has sent out a considerable number of samples for thermal analysis to engineers for comparative work. The response to the sub-committee's effort has been gratifying and it is hoped that this action will result in the establishment of standards for thermal analysis.

The sub-committees on Photography and on Micro-Hardness report satisfactory progress.

The committee recommends that the Tentative Recommended Practice for Photography as Applied to Metallography (E 7 – 23 T)[1] be accepted as standard with the understanding that this will be appended to the Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys (E 2 – 20).[2]

The Tentative Methods of Metallographic Testing of Iron and Steel (E 3 – 23 T)[3] which were revised last year and the Tentative Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 23 T)[4] which were presented last year have been favorably received and the committee recommends that both be adopted by the Society as standard.

This report has been submitted to letter ballot of the committee, which consists of 41 members, of whom 35 have voted affirmatively, none negatively, and 6 have refrained from voting.

Respectfully submitted on behalf of the committee,

W. H. BASSETT,
Chairman.

G. F. COMSTOCK,
Secretary.

EDITORIAL NOTE

The revisions of the Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys, proposed in 1921, and subsequently amended in 1923 and further amended as recommended in this report, were approved and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. The definitions, as revised, appear in the 1924 Book of A.S.T.M. Standards. The Tentative Methods of Metallographic Testing of Iron and Steel, of Metallographic Testing of Non-Ferrous Metals and Alloys and the Tentative Recommended Practice for Photography as Applied to Metallography were approved at the annual meeting, as recommended in this report, and subsequently adopted as standard by letter ballot of the Society on August 28, 1924. These standards appear in the 1924 Book of A.S.T.M. Standards.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 945 (1923).

[2] 1921 Book of A.S.T.M. Standards.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 919 (1923).

[4] *Ibid.*, p. 931.

APPENDIX

BIBLIOGRAPHY OF ETCHING

FERROUS METALS

Fry.

"Etching to Develop Overstrain," *Stahl und Eisen*, Vol. 41, pp. 1093–1097 (1921); *Chemical and Metallurgical Engineering*, Vol. 27, p. 349 (1922). Method brings out markings in overstrained steel. After polishing, the specimens are heated to 200° C. for one-half hour.

Etching Solution:

Hydrochloric Acid (concentrated)	40 cc.
Water	30 cc.
Ethyl Alcohol	25 cc.
Cupric Chloride Crystals	5 g.

After immersion, the specimen is rubbed with finely powdered cupric chloride on a rag moistened with the etching solution until desired contrast is obtained, dried without rinsing, washed with alcohol and again dried. The dark portions are due to the presence of iron hydride and indicate the amount of plastic deformation the metal has received.

Gill and Bowman.

"Metallography of High-Speed Steel," *Transactions*, Am. Soc. Steel Treating, Vol. II, pp. 184 to 205. Picric acid used for annealed samples, 6 to 8 per cent HNO_3 in alcohol best for hardened specimens. A solution of NaOH and H_2O_2 and a solution of $K_3Fe(CN)_6$ used for tungstides.

Krivobok and Sauveur.

"Use of Sodium Picrate in Revealing Dendritic Segregation in Iron Alloys," Am. Inst. Mining and Metallurgical Engrs., February, 1924.

Loskicwiz.

"Time of Attack of Micrographic Reagent on Iron-Carbon Alloys," *Revue de Metallurgie Memoires*, Vol. XIX, pp. 681 to 687 (1922). Gives time of etching with picric and nitric acid solutions in alcohol at three temperatures (16, 24 and 35° C.) for plain carbon steels. Gives also curves showing time of attack for pearlite, sorbite, troostite and martensite in a 0.9-per-cent carbon steel, and a table of basis reagents used to color cementite.

Pilling.

"Micrographic Detection of Carbides in Ferrous Alloys," Am. Inst. Mining and Metallurgical Engrs., February, 1924.

Silicon steels up to 6 per cent are attacked by water during polishing. It is necessary to use alcohol as polishing lubricant in the last stages of preparation and to avoid all etching reagents having an aqueous base. Boiling alkaline sodium picrate solution attacks the silico-ferrite.

A new reagent consists of a dilute solution of nitric acid and methyl alcohol in nitro-benzol. Make an anhydrous stock solution of 20 per cent nitric acid in methyl alcohol. The etching reagent consists of 40 drops of this solution in 50 cc. of nitro-benzol. Etch by immersion for 20 seconds. Store in dark-colored bottles.

Strauss, B., and Fry, A.

"Formation of Cracks in Boiler Plates," *Stahl und Eisen*, Vol. 41, p. 1133. Metallographic illustrations obtained by same reagents as given under Fry, above.

NON-FERROUS METALS

Chemical and Metallurgical Engineering, Vol. 24, p. 207 (1921). Gives list of the common reagents used by the Bureau of Standards, with notes on suitability. (See Bureau of Standards *Circular No. 113* (1921).)

Adcock.

"Internal Mechanism of Cold-Work and Recrystallization in Cupro-Nickel," *Journal*, Inst. of Metals, Vol. XXVII, p. 74 (1922–No. 1). Gives method of electrolytic etching in a solution of 100 g. citric acid per liter of water, add 1 drop concentrated HNO_3 per 20 cc. of solution. For ordinary micro-sections 0.1 ampere is sufficient. (A tungsten lamp in series on a 100-volt circuit.)

Rutherford.

"Etching Lead and Lead Alloys," Private Communication to Committee E-4, Rutherford, Western Electric Co. Samples flattened on coarse file, smoothed on fine file, polished on broadcloth wheel with magnesia.

Etch with:

Glacial Acetic Acid	3 parts
9-per-cent H_2O_2	1 part

or 10 to 30 minutes. Dry with alcohol and clean in concentrated nitric acid. The nitric acid is removed by sudden immersion in a large volume of water. For pure lead and lead-tin alloys, the nitric acid cleaning may be omitted.

Strauss.

"Etching Aluminum Bronze," *Chemical and Metallurgical Engineering*, Vol. 28, p. 852 (1923).

DISCUSSION

Mr. Groesbeck.

MR. E. C. GROESBECK[1] (*presented in written form*).—The writer wishes to offer the following comments on the Solutions for Carbides, etc., appearing under Reagents for Etching of the Tentative Methods of Metallographic Testing of Iron and Steel (Serial Designation: E 3 – 23 T) as published in the Proceedings of the Society for 1923:[2]

Under *Kourbatoff*, it is stated, "cementite colored. Also Fe_nW, Fe_2W_2C, etc., in tungsten steels while WC is unattacked."

The writer has noticed that in etching with a boiling alkaline sodium-picrate solution the iron tungstide particles (in iron-tungsten alloys with or without carbon) are more or less completely eaten out and dark-walled cavities are formed in their place. This may readily be seen to be the case if one repolishes the etched section lightly or till the matrix has been rubbed free from the pre-existing etching pattern, if any were formed. The same has been found to hold true, although in a less marked and general degree, for cementite in carbon steels, particularly when the cementite occurs in the massive form as globules or thick network (proeutectoid). The cementite occurring in lamellar form appears to be attacked in a similar manner, although the relative thinness of the cementite lamellae makes the existence of the voids thus formed less evident; these voids, if formed, are apparently not very deep-seated as may be judged from the fact that a light repolishing is often sufficient to remove the dark-colored cementite lamellae. Consequently the statement that the microconstituent is "colored" should not be considered as being strictly correct; the term "attacked" would be more appropriate, even though the cementite globules may be only colored on the surface in vari-colored hues.

The action produced by the alkaline sodium-picrate solution appears to be due mainly to the alkali present. The writer found that boiling aqueous sodium-hydroxide solutions, containing 10 and 25 per cent NaOH by weight, gave very similar etching results with cementite and iron tungstide to those of the alkaline sodium picrate solution. The action of either reagent (alkaline sodium picrate or simple aqueous solution of alkali) on cementite is considerably slower, particularly in the case of globular cementite, than on iron tungstide.

Since the existence of the compound Fe_2W_2C (Hultgren's Z_1 carbide—$Fe_2W.WC$; Arnold and Read believed this to be a mixture of Fe_2W and WC, although they could not distinguish between the two under the microscope or separate them by chemical means) is appar-

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[1] Associate Chemist, U. S. Bureau of Standards, Washington, D. C.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 919 (1923).

Mr. Groesbeck.

ently not well-established, it seems advisable to omit mention of this compound and to change the wording under the section on Kourbatoff to something like this:

> "Used boiling 5 to 10 min.; cementite attacked. Iron tungstide (Fe_nW) in iron-tungsten alloys and in tungsten steels also attacked, while tungsten carbide, WC, remains unattacked. Ferrite unattacked."

Referring to *Matweieff's* reagent, the writer found that a boiling neutral solution of sodium picrate readily attacks iron tungstide, present as a free constituent in laboratory-prepared iron-tungsten alloys containing little or no carbon. This solution had no effect on cementite in carbon steels after 60 minutes' immersion at boiling hot temperature.

Under *Yatsevitch* it is stated, "for high-speed steel............ Tungsten carbide darkened."

What is meant by "tungsten carbide?" Is it the same compound described under Kourbatoff as WC? Etching tests made by the writer show that the angular-shaped crystals found in a tungsten steel (received from a steel maker—chemical composition: 1.2 per cent carbon, 5.2 per cent tungsten, 0.32 per cent manganese, 0.38 per cent silicon, 0.036 per cent sulfur, and 0.017 per cent phosphorus) and corresponding in general characteristics to Hultgren's WC, are not darkened or apparently affected by Yatsevitch's reagent, although they are readily attacked by certain other etching reagents tried.

Mention may here be made that similar angular-shaped crystals of tungsten carbide were obtained in specimens of an iron-tungsten-carbon alloy, which was prepared in the laboratory and contained 11.7 per cent of tungsten and 1.6 per cent of carbon, after they had been heated to and held at 1100 to 1190° C. for 1 to $3\frac{1}{2}$ hours and either quenched in oil or cooled in the furnace. The microstructure of this alloy in the cast condition consisted of a matrix containing iron tungstide and iron carbide (cementite) distributed in a rather irregular fashion, though generally in the form of a dendritic structure. The angular-shaped crystals of tungsten carbide were evidently formed by the reaction occurring at high temperatures between iron tungstide and cementite, as suggested by Ozawa.[1] These angular-shaped crystals behaved in a similar manner toward the various etching reagents as those in the tungsten steel mentioned in the preceding paragraph.

It might appear that the "tungsten carbide" mentioned in the tentative standard refers to the free constituent generally found in the microstructure of high-speed steels as globules (in properly worked steels) or in eutectiform arrangement (in steels as cast or not suffi-

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[1] *Science Reports*, Tohoku Imperial University, Sendai, Japan, November, 1922.

Mr. Groesbeck. ciently worked). In the literature on high-speed steels, this microconstituent has been described under different names: namely,

> "Fe-W carbide" (double carbide of Fe and W)—Bain and Jeffries (*Iron Age,* September, 1923—based on their X-ray work).
>
> "Double carbides of Fe and W"—Andrew and Green (*Journal,* Iron and Steel Inst., 1919, I, p. 305).
>
> "Free carbide" and "carbide particles"—Sauveur ("The Metallography of Heat Treatment of Iron and Steel").
>
> "Tungstide"—Honda and Murakami (*Journal,* Iron and Steel Inst., 1920, I, p. 647); Gill and Bowman (*Transactions,* Am. Soc. Steel Treating, Vol. 2, p. 184, 1921).

The possibility that other elements such as chromium and vanadium (or molybdenum) may be present in this microconstituent and thus add to the complexity of its composition has been pointed out by several of these investigators.

It was found in the writer's etching tests, made on specimens of different high-speed steels, that this microconstituent is readily attacked by the same etching reagents as is iron tungstide (in carbonless iron-tungsten alloys), namely, Yatsevitch, hot alkaline sodium picrate (Kourbatoff), cold and hot aqueous sodium hydroxide solution, Murakami's reagent ($K_3Fe(CN)_6$ and alkali), etc.

Under *Murakami* is the statement that the reagent "distinguishes between carbide and tungstide in high-speed and in tungsten steels."

This would imply that both carbide and tungstide may be found in high-speed steels. Assuming that the microconstituent referred to above as being present in properly-worked high-speed steel in the form of globules is tungstide, then any carbide present should occur as a separate and distinct microconstituent.

In the writer's etching tests, Murakami's reagent used boiling hot was found to attack cementite in carbon steels, chromium carbide in chromium steels (this reagent was adopted by Murakami particularly for Cr-Fe-C alloys), tungsten carbide (angular-shaped crystals, WC—see above under Yatsevitch), and iron tungstide. The last three microconstituents are more readily attacked than cementite. It should not appear possible from these results that etching with Murakami's reagent would offer a reliable distinction between "carbide and tungstide." Etching with a hot neutral solution of potassium ferricyanide (10 g. $K_3Fe(CN)_6$ to 100 cc. H_2O) had no effect on any of the microconstituents mentioned at the beginning of this paragraph. The action produced by the hot alkaline solution is evidently due to the nascent oxygen, formed according to the following reaction, and which apparently affected all the microconstituents in preference to the iron matrix:

$$4\ K_3Fe(CN)_6 + 4KOH = 4\ K_4Fe(CN)_6 + 2\ H_2O + O_2$$

REPORT OF COMMITTEE E-6
ON
PAPERS AND PUBLICATIONS

During the year, the Committee on Papers and Publications has held two meetings, the first in December, 1923, and the second in February, 1924, at both of which the general arrangements for the program for this meeting were discussed and the offers of papers passed upon for acceptance in accordance with the Rules. Since the February meeting the Advisory Committee has acted for the committee on all matters relating to the program.

The program of the meeting is now in the hands of the members and to a large degree will speak for itself. It contains many subjects of importance. One of the outstanding features is the Symposium on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys, to which the committee has felt justified in devoting considerable time at the meeting as well as space in the Proceedings. This Symposium is the outcome of the suggestion made by Committee B-2 on Non-Ferrous Metals and Alloys, to which reference has been made elsewhere. It was believed that the Society could render an important service by gathering together the principal available data regarding the properties and uses of these alloys, and it is hoped that the Symposium will point the way to the further development of the subject in the Society on a permanent basis. An important matter for future consideration is that of further tests of these alloys to supplement existing data. The Symposium has been arranged by the following committee, acting in an advisory capacity to the Committee on Papers, and the Committee on Papers takes this opportunity of expressing its appreciation of the able services of the committee:

Jerome Strauss, *Chairman*

P. A. E. Armstrong
W. H. Bassett
L. O. Hart
A. I. Krynitsky
P. D. Merica
H. M. Williams

Another session is devoted largely to a discussion of methods of testing for corrosion. Other outstanding features are the report of the Committee on Investigation of Phosphorus and Sulfur in Steel; a session devoted entirely to methods of testing and nomenclature, in which a number of interesting reports and papers are to be presented; four papers on endurance tests of metals, contributing a fund of valuable information on this important subject; and a general discussion on the subject of cast iron for pipe. In the field of non-metals there are a number of important contributions, among the largest of which are the report of the Joint Committee on Concrete and Reinforced Concrete; several papers on various topics relating to concrete; a complete report on the wear tests of concrete pavements conducted by the U. S. Bureau of Public Roads; and several papers on such subjects as accelerated weathering, oxidation of oils, structural timbers, etc. A subject of general application and one that the Committee on Papers believes merits a full discussion is one entitled "How Shall the Benefits of A.S.T.M. Standardization be Secured to the Small User?"

Regarding the arrangement of the program, the Executive Committee of the Society approved the committee's recommendation that the plan of parallel sessions be adopted in an effort to bring the metals and non-metals groups of the Society together, thus avoiding the tendency evident the last few years of "splitting" the Society membership rather sharply into these two groups, and also by the elimination of afternoon meetings of the Society to give more time for the holding of committee meetings that will not conflict with regular Society sessions.

There are scheduled on the program 41 committee reports, which include reports from 2 joint committees, and 45 papers. Thirty-three of the reports and 30 papers have been preprinted, and of the papers that could not be put in type, summaries of eight have been printed for the meeting. The total number of pages involved is 1248 compared with 1058 pages for last year and 1225 pages for 1922.

The volume of business to be considered at the annual meeting of the Society is naturally increasing. It is becoming more difficult each year to distribute committee reports four weeks in advance of the meeting, as required by the Regulations. Both last year and again this year it has been a physical impossibility, despite the very adequate printing facilities the Society commands, to print and distribute committee reports by the time required. Thus, distribution of committee reports was not completed to those members requesting them until six days before the opening of the annual meeting. The Committee on Papers intends to give consideration to this subject and may have some recommendation to make to the Executive Committee.

In May, the Society joined with the American Society of Mechanical Engineers in arranging for a Symposium on the Effect of Temperature upon the Properties of Metals in connection with the spring meeting of our sister society. The Society was invited to prepare the program of this Symposium, for which purpose the following special committee was appointed to act in an advisory capacity to the Committee on Papers:

V. T. Malcolm, *Chairman*	H. J. French
L. W. Spring	A. E. White
R. S. MacPherran	G. W. Graham

The Committee on Papers wishes to take this opportunity of expressing its appreciation of the very able services that this committee has rendered. The meeting was distinctly successful. Four papers were prepared forming the introduction to the Symposium, and by arrangement with the A.S.M.E. these papers were edited and printed by the Society and distributed by the A.S.M.E. They formed a pamphlet of 136 pages and together with the discussion will appear in the Proceedings of both organizations.

Respectfully submitted on behalf of the committee.

C. L. WARWICK,
Chairman.

REPORT OF COMMITTEE E-8
ON
NOMENCLATURE AND DEFINITIONS

Committee E-8 is again in a position to report substantial progress during the year in harmonizing the tentative definitions of terms before it. It has also made a start in the consideration of standard definitions of terms. In giving consideration to tentative definitions it has pursued the course outlined in its report for 1922, as follows: Those definitions which clearly concern only one standing committee were reviewed by the Editorial Committee of the Advisory Committee and have been discussed with the standing committee concerned, suggestions for rewording and classification of the definitions being offered to the standing committee in question. Those terms which concern more than one standing committee were referred to suitable sub-committees. The following is the list of the present sub-committees of Committee E-8 organized for this purpose:

On Specific Gravity (F. M. Farmer, Chairman).
On Definition of Clay (A. S. Watts, Chairman).
On Definitions of Terms Relating to Cementitious Materials (L. I. Neale, Chairman).
On Definition of Sand (L. R. Ferguson, Chairman).
On Definitions of the Terms Sieve and Screen (L. R. Ferguson, Chairman).
On Definitions of Loam, Silt, Gravel and Related Terms (L. R. Ferguson, Chairman).
On Definitions of Moisture, Ash, Volatile Matter and Fixed Carbon (H. C. Porter, Chairman).

For the most part the work of these sub-committees has been handled by correspondence. The Advisory Committee of Committee E-8 held three meetings, one in November, 1923, one in February, 1924, in conjunction with the regular meeting of Committee E-8, and one in May to dispose of such matters which were left with power in the hands of the Advisory Committee by action at the regular meeting of Committee E-8. Committee E-8 met once during the year, at the Society's headquarters on February 8, 1924, at which the various sub-committee reports on definitions of terms were passed upon.

As indicated above, Committee E-8 is now giving some consideration to definitions that had already been adopted as standard. The Definitions of Terms Relating to Paint Specifications adopted in 1915 were felt to be appropriate definitions on which to make a beginning, since these definitions were to be combined with a number of definitions of terms relating to paint adopted in 1922 that had been approved by Committee E-8. It was felt that it would be well to have all definitions relating to this subject in the same status: that is, bearing the approval of Committee E-8. The definitions adopted in 1915 were brought up for consideration at a meeting of the Editorial Committee which was attended by the representative on Committee E-8 of Committee D-1 on Preservative Coatings for Structural Materials, the standing committee having jurisdiction over these definitions. A number of suggestions were made in reference to these definitions which have since been given consideration by Committee D-1. Certain recommendations are being made by that committee, the principal ones being the withdrawal of the definitions for the terms "bulk" and "voids" and a change in the wording of the definition for the term "fineness." In addition to this direct method of taking into consideration standard definitions, Committee E-8 is making further progress in passing upon standard definitions in that a number of standard definitions are replaced by tentative ones which have received the approval of Committee E-8. Among these, specific mention might be made of the definitions relating to magnetic testing, which were submitted as tentative in 1923 and are replacing a corresponding number of standard definitions upon their adoption as standard this year. Certain standard definitions relating to clay are also being replaced by definitions bearing the approval of Committee E-8, and also certain definitions of terms relating to verification of testing machines. A number of definitions of terms relating to timber are now under consideration by Committee D-7. When these are adopted as standard they will supersede a number of definitions which are now standard. Committee E-8 can accordingly report considerable progress in the review of A.S.T.M. standard definitions.

DEFINITIONS OF TERMS APPROVED BY COMMITTEE E-8

In 1922, Committee E-8 approved nine definitions of terms relating to paint and the definition of the term "A.S.T.M. Paraffin Wax Melting Point." In 1923, four definitions relating to rubber analysis were approved and are now being advanced to standard by the standing committee having jurisdiction over these terms

The complete list of the 14 terms approved by Committee E-8 is as follows:

A.S.T.M. Paraffin Wax Melting Point
Drying Oil
Enamel
Filler
Lake
Non-Drying Oil
Organic Acetone Extract
Saponifiable Acetone Extract
Semi-Drying Oil
Size
Toner
Total Waxy Hydrocarbons
Unsaponifiable Resins
Varnish

One definition, namely, that for "virgin lead" which appeared in the Specifications for Pig Lead (B 29) was rewritten as a section on scope rather than a definition. The definition accordingly was dropped from consideration by Committee E-8.

The advancement to standard of the 4 terms mentioned above and the withdrawal of the definition for the term "virgin lead" left 149 tentative definitions of terms still before Committee E-8 for consideration, including three terms not mentioned in the 1923 report and 24 terms that are a sub-classification of a term submitted in 1921 by Committee D-13 on Textile Materials. At the 1923 annual meeting 52 additional terms were submitted as tentative. The total number of terms before Committee E-8 at the present time is accordingly 201.

Tentative Definitions of Terms Submitted Prior to 1923

Of the 149 terms remaining before Committee E-8 after the 1923 annual meeting, quite a number are now being recommended for advancement to standard. Still others are remaining as tentative but have been brought into agreement with the suggestions of Committee E-8. Still others, those which have been assigned to subcommittees for development, are either being recommended for advancement to standard at this time or will require additional work before satisfactory definitions can be reported. The action taken to date on each of the terms is as follows:

Terms Relating to Coke (*D 121*).—The 15 terms defined by Committee D-5 on Coal and Coke are as follows:

Coke
Beehive Coke
By-Product Coke
Gas House Coke
Domestic Coke
Foundry Coke from Beehive Ovens
Foundry Coke from By-Product Ovens
Furnace Coke from Beehive Ovens
Furnace Coke from By-Product Ovens
Coke Breeze
Dry Coke
Moisture
Ash
Volatile Matter
Fixed Carbon

The definitions of the terms "moisture," "ash," "volatile matter," and "fixed carbon," with certain revisions suggested by the Editorial Committee are now in the hands of a representative sub-committee, of Committee E-8, under the chairmanship of H. C. Porter. The definitions of the remaining 11 terms after having been reviewed by the Editorial Committee were referred to Committee D-5. Revised definitions for these terms are being submitted by Committee D-5 with its annual report.

Terms Relating to Coal (*D 142*).—The 6 terms presented by Committee D-5 on Coal and Coke are as follows:

Moisture
Ash
Volatile Matter
Fixed Carbon
Proximate Analysis
Ultimate Analysis

Of these terms, "moisture," "ash," "volatile matter," and "fixed carbon" are now under consideration by the special sub-committee under the chairmanship of H. C. Porter, mentioned under the definitions of terms relating to coke. A revision of the term "proximate analysis" is being submitted this year by Committee D-5. It is expected that definite recommendations concerning all 6 terms will be presented next year.

Terms Relating to Gypsum (*C 11, C 22, C 23, C 36, C 37*).—The 15 terms originally defined by Committee C-11 on Gypsum are as follows:

Accelerator
Aggregate
Binder
Cement
Consistency
Mortar
Plaster
Plasticity
Retarder
Stucco
Wood Fiber
Gypsum
Calcined Gypsum
Gypsum Wall Board
Gypsum Plaster Board

In addition, a definition for the term "lath" was added to the Tentative Definitions C 11 in 1922. A definition for the term "crushed gypsum" has recently been prepared by Committee C-11 and is being considered in conjunction with the terms "gypsum," "calcined gypsum," "gypsum wall board," and "gypsum plaster board" mentioned above. Rewordings of these definitions were suggested by the Editorial Committee and were referred to Committee C-11. Agreement has now been reached on these definitions between Committee C-11 and Committee E-8 and they are being recommended for advancement to standard by Committee C-11. They have been referred to letter ballot of Committee E-8 for approval, the results of the letter ballot vote being as follows: Advisory Committee, 6 affirmative, 0 negative, 1 not voting, total, 7; Standing Committees, 19 affirmative, 1 negative, 16 not voting, total, 36.

The definitions of the terms "consistency" and "plasticity" are still receiving discussion in a sub-committee of Committee E-1 on Methods of Testing. The term "aggregate" has been referred for development to the Sub-Committee on Sand under the chairmanship of L. R. Ferguson. The remaining terms given above: namely, "accelerator," "binder," "cement," "mortar," "plaster," "retarder," "stucco," and "wood fiber" have been referred to the newly organized Sub-Committee on Cementitious Materials. Some work has already been accomplished in the study of these definitions and a further report will be made next year.

Terms Relating to Lime (C 51).—The 5 terms defined by Committee C-7 on Lime are as follows:

Quicklime
Hydrated Lime
Lump Lime
Lump Lime Screened
Pulverized Lime

Committee E-8 gave these definitions an editorial review and believing that Committee C-7 was the only standing committee concerned with the definitions, referred them back to that committee with a number of suggestions for rewording. Committee C-7 brought out some further points requiring discussion and after a subsequent review by Committee E-8 the definitions were again referred to Committee C-7. Committee C-7 has approved the latest revisions and these are being submitted this year in the annual report of the committee. They are being kept as tentative, however, so the definitions have not as yet been referred to the membership of Committee E-8 for approval, Committee E-8 believing it better to defer conducting letter ballots on definitions until such definitions are being recommended for advancement to standard.

Terms Relating to Hollow Tile (C 43).—The 26 terms originally defined by Committee C-10 on Hollow Building Tile are as follows:

Clay Hollow Tile
Terra Cotta
Hollow Building Tile
Load-Bearing Tile
Floor Tile
Foundation Tile
Side-Construction Tile
End-Construction Tile
Back-up Tile
Book Tile
Hollow Tile Fireproofing
Partition Tile
Furring Tile
Porous Tile
Vitrified Tile
Salt-Glazed Tile
Shale
Fire Clay
Surface Clay
Thickness
Width
Length
Shells
Webs
Cells
Scoring

At the suggestion of Committee E-8 a definition for "split tile" was subsequently included. Committee C-10 has since withdrawn the definitions for the terms:

Terra Cotta
Hollow Building Tile
Back-up Tile
Vitrified Tile

The definitions were recommended by Committee C-10 in 1923 for advancement to standard. The question was raised, however, as to whether the definitions as worded were universally applicable. In order to give the matter further study the recommendation for advancement to standard was withdrawn by Committee C-10 on the floor of the annual meeting. The definitions have since been revised and have been given a careful review in Committee E-8. They are now being recommended for advancement to standard in their revised form and have been submitted to letter ballot of Committee E-8 for approval. The results of this letter ballot vote are as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total, 7; Standing Committees, 10 affirmative, 1 negative 25 not voting, total, 36. The definitions include definitions for the terms "surface clay," "fire clay," and "shale" which were prepared by the Sub-Committee on Clay and are now being put forth as standard definitions. Further reference is made to these terms in discussing the work of this sub-committee.

Terms Relating to Textiles (*D 122, D 123*).—The terms relating to textiles including those submitted in 1922 by Committee D-13 on Textile Materials are 45 in number.

Those appearing in the Tentative Specifications D 122 are as follows:

Major Defects

Thick Places
Thin Places
Missing Warp Thread
Pucker
Bad Start-up

Minor Defects

Thick Places
Thin Places
Slack Threads
Tight Threads
Slugs
Sewed Thread
Knots
Mispick or Broken Pick
Float
Reed Mark
Split or Chafed Yarn
Dirty Yarn
Wrong Ply Warp Thread
Wrong Draw

Special Defects

Oil Spots
Mixed Filling, Inferior Grade
Smashes
Imperfect Selvage
Wrong Ply Filling Threads

Those appearing in the Tentative Definitions of Terms D 123 are the following:

Alberts
Army Duck
Balata Belt Duck
Clay (a kind of weave)
Crimp
Drills
Enameling Duck
Hose Duck
Jeans
Numbered Duck
Off-Square
Oil Belt Duck
Rubber Belt Duck
Serge
Single Filled or Flat Duck
Tire Builder Fabric
Tire Cord Fabric
Twill

Since it was apparent that Committee D-13 was the only standing committee concerned, the definitions were discussed directly with that committee without the appointment of a sub-committee. Rewordings of a number of the definitions were submitted by the Editorial Committee and these for the most part have been accepted by Committee D-13. The definitions are in generally acceptable form. No final action has been taken by Committee E-8, however, since the definitions are not expected to be advanced to standard at the present time.

Terms Relating to Waterproofing Materials (*D 147*).—The three terms submitted by Committee D-8 on Waterproofing Materials are as follows:

Bituminous Grouts
Bituminous Mastics
Mastic Cake

As a result of rewordings suggested by Committee E-8, Committee D-8 revised these definitions in 1923, the terms at the same time being changed to "bituminous grout," "asphalt mastic," and "asphalt mastic cake." In making the revisions some additional material was added and the definitions came up for further consideration during the year. The revised definitions are being submitted by Committee D-8 which bring these definitions in close agreement with suggested rewordings of Committee E-8. Since, however, the definitions are not being recommended for advancement to standard no formal action has been taken on the definitions by Committee E-8.

Terms Relating to Timber (*D 23*).—The 10 terms defined by Committee D-7 are as follows:

Annual Ring
Summer Wood
Dense Douglas Fir
Sound and Tight Knot
Encased Knot
Loose Knot
Rotten Knot
Ring Shake
Round Shake
Diagonal Grain

A number of suggestions for rewordings of these definitions were referred to Committee D-7 for consideration. Committee D-7 is now making an extended study of all definitions relating to timber, and as a result of this study it is expected that revised definitions for the terms will be submitted. This subject is discussed later in the report.

Terms Relating to Metallography (E 2).—Committee E-4 on Metallography prepared definitions for the following 18 terms:

- Achromatic
- Alloy
- Alpha Brass
- Apochromatic
- Etching Reagent
- Equi-axed
- Grain
- Grain Size
- Illuminator
- Intercept Method for Grain Count
- Lens
- Achromatic Objectives
- Macrograph
- Magnification
- Metal
- Micrograph
- Muntz Metal
- Planimetric Method for Grain Count

As a result of a critical review of these definitions by Committee E-4 and Committee E-8 jointly, the definitions have been extensively revised. The definitions for the following terms have been withdrawn:

- Achromatic
- Achromatic Objectives
- Apochromatic
- Equi-axed
- Illuminator
- Intercept Method for Grain Count
- Lens
- Muntz Metal
- Planimetric Method for Grain Count

Definitions for the terms "beta brass" and "equi-axed grain" were inserted. The revised definitions are now being recommended by Committee E-4 for advancement to standard. They have been submitted to letter ballot of Committee E-8 for approval, the results of this letter ballot vote being as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total 7; Standing Committees, 15 affirmative, 1 negative, 20 not voting, total 36.

Miscellaneous Terms.—There are 6 terms classed as miscellaneous:

- Ductility (D 113)
- A.S.T.M. Lubricating Oil Precipitation Number (D 91)
- Cloud Point (D 97)
- Pour Point (D 97)
- A.S.T.M. Petrolatum Melting Point (D 127)
- Specific Gravity (D 70, D 71)

The definition of "ductility" (as given by Committee D-4 on Road and Paving Materials) as applying to the ductility of asphalt cement was referred back to Committee D-4, since it was felt by Committee E-8 that the definition as worded could scarcely be considered a definition of ductility but rather a description of how that property is determined. Committee D-4 is contemplating revising the methods in which this definition appears. The definition of "ductility" will come up for consideration in conjunction with this general revision.

Definitions for terms relating to specific gravity are in preparation by the Sub-Committee, of Committee E-8, on Specific Gravity, under the chairmanship of F. M. Farmer. The progress in the development of these definitions is reported later in connection with the work of that sub-committee. The definition for the term "A.S.T.M. Petrolatum Melting Point" has been reviewed by Committee E-8 and discussed with Committee D-2 on Petroleum Products and Lubricants having jurisdiction over this definition. Agreement has been reached on a satisfactory wording for the definition and it has been referred to letter ballot of Committee E-8 for approval, the results of this letter ballot vote being as follows: Advisory Committee, 6 affirmative, 0 negative, 1 not voting, total, 7; Standing Committees, 17 affirmative, 0 negative, 19 not voting, total, 36. Definitions for the terms "cloud point," "pour point" are still under consideration by the appropriate sub-committees of Committee D-2. The term "A.S.T.M. Lubricating Oil Precipitation Number" has been approved by Committee D-2 and is still under consideration by Committee E-8.

TENTATIVE DEFINITIONS OF TERMS PRESENTED IN 1923

The definitions of terms, 52 in number, submitted in 1923 are grouped according to subject matter, and the standing committees responsible for them, as follows:

	COMMITTEE PROPOSING DEFINITION	NUMBER OF TERMS DEFINED
Terms Relating to Magnetic Testing (A 34)	A – 6	7
" " " Textiles (D 179)	D – 13	24
" " " " (D 180)	D – 13	1
" " " Verification of Testing Machines (E 4)	E – 1	6
" " " Methods of Testing (E 6)	E – 1	12
Miscellaneous Terms:		
Toughness (D 16)	D – 1	1
Elasticity of Paint and Varnish Films (D-16)	D – 1	1
		52

Terms Relating to Magnetic Testing (A 34).—The 7 terms defined by Committee A-6 on Magnetic Properties are as follows:

Normal Induction
Magnetic Permeability
Residual Induction
Coercive Force
Core Loss
Standard Core Loss
Aging Coefficient

After a review by the Editorial Committee of Committee E-8, they were referred to Committee A-6 since this was the only committee interested in these definitions. The recommendations of the Editorial Committee were satisfactory and the definitions are now being recommended by Committee A-6 for advancement to standard. They have been referred to letter ballot of Committee E-8 for approval, the results of this letter ballot vote being as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total, 7; Standing Committees, 11 affirmative, 0 negative, 25 not voting, total, 36.

Terms Relating to Textiles (D 179, D 180).—The 25 terms submitted by Committee D-13 on Textile Materials in 1923 are as follows:

Major Defects

Thick Places
Thin Places
Missing Cord
Knots of Finished Cord

Direction of Twist

Minor Defects

Thick Places
Thin Places
Slack Cord
Tight Cord
Slugs
Mispick or Broken Pick
Float
Chafed Cord
Dirty Yarn
Wrong Ply Cord
Wrong Draw
Corkscrew Twist
Kinks

Special Defects

Oil Spots
Smashes
Imperfect Selvage
Baggy Fabrics
Irregular Picks
Mixed Cords
Defective Splice

Most of these definitions are of the same type as those appearing in Specifications D 122; in fact, in some cases the same definition appears in both standards. The new definitions are accordingly being considered in conjunction with those submitted in previous years. They are being discussed with Committee D-13 and no difficulty is expected in arriving at satisfactory definitions.

Terms Relating to Verification of Testing Machines (E 4).—The following 6 definitions were prepared by Committee E-1 on Methods of Testing and submitted in conjunction with methods for the verification of testing machines:

Testing Machine
Error
Percentage of Error
Correction
Tolerance
Loading Range

These definitions had been referred to Committee E-8 by Committee E-1 prior to their submission as tentative definitions. Having been prepared through the cooperation of these two committees they required very little review subsequent to their submission to bring them in line with the usual form. They are now being recommended for advancement to standard by Committee E-1 and have been referred to letter ballot vote in Committee E-8 for approval, the results of this letter ballot vote being as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total, 7; Standing Committees, 28 affirmative, 0 negative, 8 not voting, total, 36.

Terms Relating to Methods of Testing (*E 6*).—Committee E-1 submitted definitions of the following 12 terms:

Tension
Compression
Shear
Flexure
Torsion
Stress
Strain
Stress-Strain Diagram
Elastic Limit
Yield Point
Tensile Strength or Ultimate Tensile Strength
Modulus of Elasticity

These definitions received considerable discussion on the floor of the annual meeting and subsequently in Committee E-1 and Committee E-8. As a result of this discussion the definitions of 5 of these terms were withdrawn as tentative, namely,

Tension
Compression
Shear
Flexure
Torsion

Revised definitions of these terms are being presented in the Report of Committee E-1 as information.

The remaining terms have been revised and are now being resubmitted as tentative definitions.

Miscellaneous Terms.—Committee D-1 on Preservative Coatings for Structural Materials submitted definitions for the terms "toughness" and "elasticity of paint and varnish films." These are presented as proposed additions to the Standard Definitions of Terms Relating to Paint Specifications (D 16). They are still under consideration by the Sub-Committee, of Committee D-1, on Nomenclature and Definitions.

Briefly summarizing the work of the committee on the definitions submitted by the various standing committees, it may be said that 204 such terms have been before the committee this year. Sixteen have been withdrawn by the committees that proposed them, 135 are being continued as tentative and 53 are being recommended by the respective standing committees for advancement to standard, with the formal approval of Committee E-8. Of the 135 terms continued as tentative, Committee E-8 has proposed revisions in nearly all and, with respect to considerably more than half, the recommendations of the committee are satisfactory to the standing committees concerned. Formal approval of the committee, however, has been deferred until the standing committees are prepared to recommend the definitions for adoption as standard.

RÉSUMÉ OF SUB-COMMITTEE AND OTHER ACTIVITIES

Sub-Committee on Specific Gravity.—This sub-committee, under the chairmanship of F. M. Farmer, made a comprehensive study of definitions for the terms relating to "specific gravity" as given in various standards of the Society, in many standard dictionaries, textbooks and other references. A report of this sub-committee[1] was appended to the 1923 report of Committee E-8. This report received considerable discussion in the several standing committees of the Society. The views of several of the committees on the report of the sub-committee are set forth in a report appended to the Report of Committee D-4 on Road and Paving Materials. The committees endorsing this report are Committee D-4, Committee D-8 on Waterproofing Materials and Committee D-7 on Timber. After making a thorough study of the various comments received from the standing committees, the chairman of the sub-committee prepared an analysis which is appended hereto. This report also includes definitions for the terms "absolute specific gravity," "specific gravity," "bulk specific gravity" and a definition which for the want of a better term may be considered a definition for the term "apparent specific gravity." These definitions are presented as information. After further review and consideration they may be submitted at some future time as tentative definitions of terms.

Sub-Committee on Clay and Related Terms.—After a careful study of the definitions for the terms "clay," "surface clay," "fire clay," and "shale" the sub-committee, under the chairmanship of A. S. Watts, appointed to consider these terms, prepared proposed definitions. A further definition, namely, the definition for the term "clay separate" was added.

These definitions were referred to the various standing committees interested and to a number of outside experts. They were further reviewed by the Editorial Committee. A final report was presented by the sub-committee, and the definitions in the following form are now being recommended for approval as standard definitions:

Clay.—An earthy or stony mineral aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry and vitreous when burned at a sufficiently high temperature.

Surface Clay.—An unconsolidated, unstratified clay, occurring on the surface.

Fire Clay.—A sedimentary clay of low flux content.

NOTE.—It is usually associated with coal measures.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 534 (1923).

Shale.—A thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.

Clay Separate.—That portion of a soil or clay which has a grain size of 0.001 mm. or less.

They have been referred to letter ballot of Committee E-8, the results of the letter ballot vote being as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total, 7; Standing Committees, 13 affirmative, 1 negative, 22 not voting, total, 36.

If accepted as standard they are to replace definitions for the corresponding terms as appearing in the standards under the jurisdiction of Committee C-3 on Brick, Committee C-4 on Clay and Cement Sewer Pipe, Committee C-6 on Drain Tile and Committee C-10 on Hollow Building Tile. Recommendations to this effect will be made at the annual meeting. Since no committee has a definition corresponding to the definition for the term "clay separate" it is recommended that this definition be incorporated with definitions for the terms "loam," "silt," etc., in which Committee C-9 on Concrete and Concrete Aggregates has expressed an interest and which may be prepared at some future time.

Sub-Committee on Definitions of Sand and Aggregate.—Under the chairmanship of L. R. Ferguson, this sub-committee has given further consideration to the definition of the term "sand" published in the report of Committee E-8 for 1923. The definition was referred to the standing committees of the Society so that it might receive considerable publicity and elicit comments which would prove of value in arriving at a satisfactory definition. It is now recommended by Committee E-8 that the definition for the term "sand" as given below be published as a tentative standard:

"*Sand.*—The fine granular material naturally or artificially produced by the disintegration or crushing of rock or slag.

"NOTE.—When used without a qualifying adjective it is generally understood to mean a product of the natural disintegration of siliceous or calcareous rock. The size of particle and other physical characteristics should properly be taken care of in specifications and therefore no limits are mentioned in the definition."

The definition has been referred to letter ballot of Committee E-8, the result of the letter ballot vote being as follows: Advisory Committee, 7 affirmative, 0 negative, 0 not voting, total, 7; Standing Committees, 19 affirmative, 1 negative, 16 not voting, total, 36.

Sub-Committee on Moisture, Ash, Volatile Matter and Fixed Carbon.—The definitions before this sub-committee, of which H. C. Porter is chairman, appear in the Tentative Definitions of Terms Relating to Coal and the Definitions of Terms Relating to Coke.

The personnel of the committee is sufficiently representative to include other interests so that the final definitions arrived at by this sub-committee should be broad enough to be applicable to all materials respecting which these definitions are of interest.

Sub-Committee on Definitions of Sieve and Screen.—After a careful review of various definitions of the terms "sieve" and "screen," the important question being to learn if any distinction existed between a sieve and a screen and if so whether this distinction consisted in a difference in shape of apertures or type of apparatus, the sub-committee, under the chairmanship of L. R. Ferguson, centered its attention on a definition for the term "screen" which would eliminate any distinction that might have been recognized in the past between the terms "sieve" and "screen," making these terms synonymous and interchangeable. The definition reads as follows:

"*Screen* (*Sieve*).—A metal plate or wire cloth, with closely spaced apertures, mounted on a suitable frame or holder, for use in separating materials according to size.".

The definition is here presented as a matter of information and to develop discussion.

Definitions of Terms Relating to Timber.—Committee D-7 on Timber is making an extensive study of all definitions of terms relating to timber. This is being made in cooperation with the Central Committee on Lumber Standards which initiated the study. As a result of this cooperative work Committee D-7 has selected from a list prepared by the Central Committee those definitions which are of immediate interest in the work of Committee D-7. The definitions will be brought up for consideration in Committee E-8 during the coming year.

This report has been submitted to letter ballot of the committee with the following results: Advisory Committee, affirmative 7, negative 0, not voting 0, total, 7; Standing Committees, affirmative 24, negative 0, not voting 12, total 36.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

C. L. WARWICK,
Ex-Officio Secretary.

EDITORIAL NOTE

The proposed Tentative Definition of the Term Sand was accepted for publication as tentative, as recommended in this report, and appears on page 851.

APPENDIX

MEMORANDUM ON SPECIFIC GRAVITY

There was appended to the 1923 annual report of Committee E-8 the report of the Sub-Committee on Specific Gravity in which four terms and definitions were recommended for standardization. Committee E-8 was not prepared to make a recommendation at that time and published the report on specific gravity as information and for the purpose of getting further criticisms and comments to aid it in arriving at a decision on this important subject. Further, many of the standing committees had not responded to the specific request for their views on the proposal.

The following is a summary of the comments of standing committees:

Committees A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8, B-3, C-1, C-5, C-6, C-10, C-11, D-9, D-13, D-14 and E-4.—Either not concerned with specific gravity or prepared to accept the proposals as published.

Committee D-1.—This committee took a letter ballot on the proposals. The results differed on the different definitions proposed but substantially 60 to 70 per cent of the membership was in favor of all four definitions as recommended, while from 30 to 40 per cent were opposed to one or more of the four definitions.

Committee D-5.—Approved the definitions after the inclusion of a note indicating the meaning of "permeable" and "impermeable portions" which has been agreed to.

Committee D-7.—Practically the same comment as Committee D-5.

Committees D-4 and D-8.—These committees offered certain minor changes, some of which have been accepted by the sub-committee.

The sub-committee was instructed by the advisory committee of Committee E-8, at its meeting in November, to prepare definitions for density. In undertaking the formulation of these definitions, three difficulties were encountered: (*a*) mass is determined by weight and therefore the exact result depends upon the method of weighing, altitude, air density, etc., so that a rigid definition becomes somewhat cumbersome; (*b*) standard units would have to be agreed upon if density is to afford the same ready comparison of different materials as specific gravity; and (*c*) long established practice in scientific circles applies the adjective "apparent" to weight and mass determinations made in air, that is, uncorrected to vacuum. This usage is in conflict with one of the proposed definitions for specific gravity where "apparent" is applied to one of the specific gravities of a porous material—a usage which is well established in certain industries and in some of the A.S.T.M. standards.

The sub-committee therefore considers it inadvisable to attempt to prepare definitions for density and recommends that no reference whatever be made to it, that is, it withdraws the recommendations made at the end of its report published in 1923.

As to the use of the adjective "apparent" for one of the specific gravity definitions, L. B. Tuckerman, of the U. S. Bureau of Standards, has given the matter careful study and recommends that the word "apparent" be not used in connection with specific gravity but be replaced by some other word. The sub-committee is unable to suggest a suitable substitute. The term "vesicular" has been proposed as fully descriptive for this particular form of specific gravity, but unfortunately it is not a generally familiar term.

Summarizing, Committee E-8 is substantially in agreement on the revised report of the Sub-Committee on Specific Gravity including the following definitions. It was deemed advisable to publish them informally in this report, particularly to get suggestions for a suitable term for definition No. 3.

PROPOSED DEFINITIONS

1. *Absolute Specific Gravity* (of solids and liquids).—The ratio of the weight referred to vacuum of a given volume of the material at a stated temperature to the weight referred to vacuum of an equal volume of distilled water at a stated temperature. It shall be expressed thus:

$$\text{Absolute Specific Gravity } \frac{x^\circ \text{ C.}}{y^\circ \text{ C.}} \ldots\ldots\ldots\ldots$$

where the temperature above the line is that of the material and the temperature below the line is that of the water.

2. *Specific Gravity* (of solids and liquids).—The ratio of the weight in air of a given volume of the material at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. It shall be expressed thus:

$$\text{Specific Gravity } \frac{x^\circ \text{ C.}}{y^\circ \text{ C.}} \ldots\ldots\ldots\ldots$$

where the temperature above the line is that of the material and the temperature below the line is that of the water.

3. .... *Specific Gravity* (of solids).—The ratio of the weight in air of a given volume of the impermeable portion of a permeable material (that is, solid matter plus impermeable pores or voids) at a stated temperature to the weight in air or an equal volume of distilled water at a stated temperature. It shall be expressed thus:

$$\text{.......................... Specific Gravity } \frac{x^\circ\text{ C.}}{y^\circ\text{ C.}} \text{ ....}$$

where the temperature above the line is that of the material and the temperature below the line is that of the water.

4. *Bulk Specific Gravity* (of solids).—The ratio of the weight in air of a given volume (including both permeable and impermeable voids normal to the material) of a permeable material at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. It shall be expressed thus:

$$\text{Bulk Specific Gravity } \frac{x^\circ\text{ C.}}{y^\circ\text{ C.}} \text{ ....}$$

where the temperature above the line is that of the material and the temperature below the line is that of the water.

NOTE.—The terms "permeable" and "impermeable" cannot be rigidly defined for a general application. The exact meaning in a particular application is the arbitrary one inferred by the procedure specified for determining the specific gravity of the material in question.

The sub-committee invites criticisms and comments on these proposed definitions, particularly suggestions for a suitable adjective for definition No. 3.

Respectfully submitted on behalf of the Sub-Committee on Specific Gravity,

F. M. FARMER,
Chairman.

A.S.T.M.
TENTATIVE STANDARDS

SUBMITTED OR REVISED

AT THE

1924 ANNUAL MEETING

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards its adoption as standard.

Members of the Society and others are invited to direct written criticism of any of these Tentative Standards to the officer of the appropriate committee whose name and address appear in the footnote to the title of each Tentative Standard.

TENTATIVE SPECIFICATIONS
FOR
CARBON TOOL STEEL[1]

Serial Designation: A 71 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1917; REVISED, 1920, 1921, 1924

Material Covered. 1. (*a*) These specifications cover carbon tool steels, the composition of which shall be as agreed upon by the purchaser and vendor, with the permissible variations specified in Section 4.

(*b*) These steels are suitable for lathe and planer tools, drills and milling cutters, dies and other miscellaneous purposes, etc.

I. MANUFACTURE

Process. 2. The steel shall be made either by the crucible or electric furnace process.

Annealing. 3. The material shall be furnished unannealed unless otherwise specified.

II. CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The composition of the tool steels shall be as agreed upon by the purchaser and vendor with the following permissible variations in composition:

		Permissible Variation, per cent	
		Over	Under
Carbon		0.05	0.05
Manganese	when under 1.00	0.10	0.10
	when over 1.00	0.20	0.20
Phosphorus		0.005	....
Sulfur		0.005	....
Silicon		0.15	0.15

Other elements as agreed.

Method of Sampling. 5. (*a*) Milled samples for analysis shall be taken from the sample bar to represent the full cross-section, or drillings shall be taken by drilling a bar midway between the center and the surface, parallel to the axis of the bar. In either case the decarburized material shall be rejected.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. G. H. Woodroffe, Secretary of Committee A-1 on Steel, Parkesburg Iron Co., Parkesburg, Pa.

(*b*) In general, the minimum depth to which the surface shall be removed before a sample is taken shall be in accordance with the following requirements:

THICKNESS OR DIAMETER, IN.	MATERIAL REMOVED, IN.
1 or under	$\frac{1}{32}$
Over 1 to $2\frac{1}{2}$, inclusive	$\frac{1}{16}$
Over $2\frac{1}{2}$ to 4, inclusive	$\frac{1}{8}$
Larger sizes	As agreed

(*c*) In the case of drill rod and other material of similar finish where freedom from decarburization is specified, samples shall be taken from the surface in addition to the methods described in Pargraph (*a*).

Standard Methods of Analysis. 6. In case of dispute, the chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1]

III. MANUFACTURING TOLERANCES IN DIMENSIONS

7. Variations in the cross-sectional dimensions of the material shall not exceed the following amounts:

FORGED AND ROLLED MATERIAL

	PERMISSIBLE VARIATION, IN.	
	OVER	UNDER
$\frac{1}{2}$ in. or under	0.010 ($\frac{1}{100}$)	0.010 ($\frac{1}{100}$)
Over $\frac{1}{2}$ in. to 1 in., inclusive	0.015 ($\frac{1}{64}$)	0.015 ($\frac{1}{64}$)
Over 1 in. to $1\frac{1}{2}$ in., inclusive	0.031 ($\frac{1}{32}$)	0.031 ($\frac{1}{32}$)
Over $1\frac{1}{2}$ in. to 2 in., inclusive	0.046 ($\frac{3}{64}$)	0.031 ($\frac{1}{32}$)
Over 2 in. to 4 in., inclusive	0.125 ($\frac{1}{8}$)	0.031 ($\frac{1}{32}$)
Over 4 in. to 6 in., inclusive	0.156 ($\frac{5}{32}$)	0.031 ($\frac{1}{32}$)
Over 6 in. to 8 in., inclusive	0.188 ($\frac{3}{16}$)	0.063 ($\frac{1}{16}$)
Over 8 in.	0.250 ($\frac{1}{4}$)	0.063 ($\frac{1}{16}$)

FINISHED MATERIAL (DRILL ROD)

$\frac{7}{16}$ in. and under	0.0005	0.0005
Over $\frac{7}{16}$ in.	0.001	0.001

IV. FINISH

Finish. 8. (*a*) The material shall be free from injurious defects and shall have a workmanlike finish.

(*b*) All drill rods shall be coated with a rust preventive.

V. MARKING

Marking. 9. (*a*) Identification marks shall be stamped on the material as agreed by the vendor and the purchaser. All identification marks shall be about $\frac{1}{4}$ in. in height when the size permits.

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[1] 1924 Book of A.S.T.M. Standards.

(*b*) In lieu of marking as specified in Paragraph (*a*), the ends of bars and rods may be painted as agreed by the vendor and the purchaser.

Bundling Small Sizes.

10. All rods and bars of which the largest cross-sectional dimension is $\frac{3}{8}$ in. or less shall be boxed or bundled, each box or bundle to contain bars or rods of the same size, shape and class of material. A metal tag shall be securely attached to the wrapping wire or box. Rods and bars of cross-sectional dimensions exceeding $\frac{3}{8}$ in. and not exceeding $1\frac{1}{2}$ in., where convenient to vendor and purchaser, may be bundled and marked as specified above. Bundles shall be of suitable size to permit easy handling and shall be securely fastened.

VI. INSPECTION AND REJECTION

Inspection.

11. The vendor shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Comparison with Selective Sample.

12. The steel shall correspond in quality and characteristics to the samples submitted under the specifications and approved by the purchaser.

Rejection.

13. Material which does not conform to the chemical composition and specified dimensional variations, or which at any time shows injurious defects inherent in the steel, will be rejected and the vendor shall be notified.

APPENDIX

TENTATIVE RECOMMENDED PRACTICE IN THE HEAT TREATMENT OF PLAIN CARBON TOOL STEEL[1]

General.—This specification covers the process to be followed in the heat treating of plain carbon tool steel.

PART I.—NORMALIZING OF TOOL STEEL BEFORE HARDENING

Process.—Operations:

Heating.
Cooling.

Heating: Place steel into furnace so as to expose maximum surface area. Heat uniformly to a temperature above the upper critical point indicated in Table I, and hold at this temperature for sufficient time to obtain complete penetration of heat and refinement of grain.

Cooling: Remove from furnace and cool freely in air.

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[1] This is a tentative Recommended Practice approved by the Standards Committee of the American Society for Steel Treating and is published by permission of that Society.

TABLE I.—NORMALIZING

CARBON RANGE, PER CENT	NORMALIZING TEMPERATURE DEG. FAHR.	NORMALIZING TEMPERATURE DEG. CENT.
0.65 – 0.80	1475 – 1525	800 – 830
0.80 – 0.95	1475 – 1500	800 – 815
0.95 – 1.10	1500 – 1575	815 – 860
1.10 – 1.25	1575 – 1650	860 – 900

CROSS SECTIONS, WEIGHT AND TIME

THICKNESS OF LARGEST SECTION OF UNIT	WEIGHT OF UNIT, LB. (APPROXIMATE)	APPROXIMATE TIME OF HEATING, HR.	APPROXIMATE TIME OF SOAKING HR.
Up to and including 1 in.	Up to 1000	$\frac{3}{4}$	$\frac{1}{2}$
Over 1 in. and including 2 in.	Over 100 and including 300	$1\frac{1}{4}$	$\frac{1}{2}$
Over 2 in. and including 3 in.	Over 300 and including 500	$1\frac{3}{4}$	$\frac{3}{4}$
Over 3 in. and including 4 in.	Over 500 and including 1000	$2\frac{1}{4}$	1
Over 4 in. and including 5 in.	Over 1000 and including 1500	$2\frac{3}{4}$	1
Over 5 in. and including 8 in.	Over 1500 and including 2000	$3\frac{1}{2}$	$1\frac{1}{2}$

PART II.—HEAT TREATING OF PLAIN CARBON TOOL STEEL

Process.—Operations:

Heating for quenching.
Quenching.
Tempering or drawing.

Heating: Heat the steel uniformly to the temperature indicated in Table II.

Quenching: Quench from this temperature in water, but do not cool below temperature of boiling water (212° F.).

TABLE II.—HEAT TREATING.

CARBON RANGE, PER CENT	HARDENING TEMPERATURE, DEG. FAHR.	QUENCHING MEDIUM AND ITS TEMPERATURE
0.65 – 0.80	1550 – 1450	Water at 70° F.
0.81 – 0.95	1460 – 1410	Water at 70° F.
0.96 – 1.10	1390 – 1430	Water at 70° F.
1.11 – 1.25	1380 – 1420	Water at 70° F.

Tempering or Drawing: Reheat immediately in oil or salt ($NaNO_3$) or furnace for the time and at the temperature specified in Table III and cool.

TABLE III.—TEMPERING ON DRAWING TOOL STEEL

RESULTS DESIRED	TEMPERING MEDIUM	TEMPERATURE, DEG. FAHR.
Relieving Strains	Oil	350 to 375
Strain Relieving and Reduction of Brittleness	Oil	400 to 500
To Relieve Strains and Toughen	Oil	500 to 600

NOTES ABOUT THE PROCESS

1. *General.*—The recommended practice for the heat treatment of tool steel applies to highest quality performance of tools for general purposes only. For specific applications where special structural requirements seem to be necessary, deviation from the recommended practice must be left to the judgment of the individual heat treater or metallurgist.

2. *Normalizing.*—A normalizing treatment for all tool steels is recommended to obtain a uniform and refined grain structure, which enables the operator to predict the behavior and performance of the steel tool during heating and quenching for hardening.

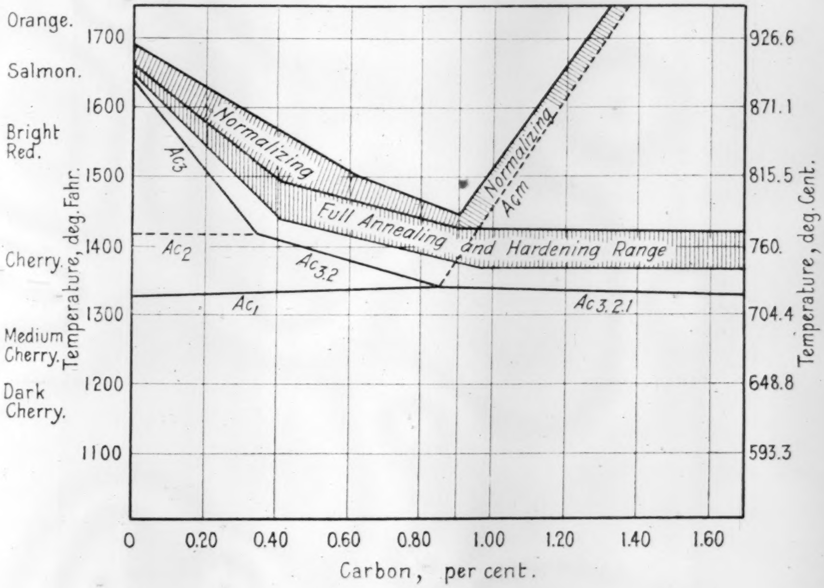

FIG. 1.—Critical Range Diagram for Iron-Carbon Alloys, showing Normalizing, Annealing and Hardening Ranges.

The variation in temperature for the different carbon ranges becomes evident upon a careful examination of the critical range diagram. A temperature very much in excess of that required to produce solid solution (austentite) is conducive of austenitic grain growth and intergranular weakness.

A low normalizing temperature for high-carbon steels (1.25 to 1.50 per cent carbon) which fails to break up the massive cementite results in a brittle structure, since the rate of diffusion of the excess cementite depends upon the temperature. The solubility of carbide in iron being greater, or increases as the temperature rises, the rate of this solubility is equivalent to the slope of the Acm. line in the diagram.

The higher normalizing temperatures given in Table I apply to the lower carbon ranges and the lower temperature to the higher carbon ranges for steel of the hypo-eutectoid composition, or, in other words, "the normalizing temperatures for hypo-eutectoid steels varies indirectly as the carbon percentage rises or falls, and the normalizing temperature of hyper-eutectoid steels varies directly with the percentage of carbon."

3. *Heating for Quenching.*—(*a*) The wide range of temperature in the 0.65 to 0.80 per cent carbon steel is needed, as a number of tools such as shear blades, arbors, mandrels, and others are all around the low point, and, because of mass and forms, require somewhat higher temperatures for quenching.

(*b*) The quenching temperatures given are at the lowest temperature range consistent with highest quality tools; deviations from it are not recommended, but may be practical for diverse reasons.

Quenching.—Water is the universal quenching medium, and by varying its temperature and manner of application for the abstraction of heat, almost any degree of variation of structural conditions of the tool steel can be obtained. There are, however, special cases where oil may be a more suitable quenching medium.

CARBON STEELS SUITABLE FOR VARIOUS USES

Carbon Content 0.65 to 0.85 Per Cent.—Shear blades, boiler snaps and cups, hammers, stamping and pressing dies, mining drills.

Carbon Content 0.81 to 0.95 Per Cent.—Hot and cold sets, chisels, dies, shear blades, mining drills, smiths' tools, set hammers, swages, flatteners.

Carbon Content 0.96 to 1.10 Per Cent.—Small cold chisels, hot sets, small shear blades, large pinchers, large taps, granite drills, trimming dies, turning tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, threading dies.

Carbon Content 1.11 to 1.25 Per Cent.—Small cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, razors, etc.

SUITABLE TEMPERING HEATS FOR VARIOUS TOOLS

Temperatures, 350 to 390° F.—Lathe tools for brass and copper alloys. Milling cutters for brass and copper alloys. Scraper and cutting tools for soft metals and micarta. Drawing mandrels, drawing dies, bone-cutting tools, hammer-faces, steel engraving tools, wood-carving tools, cutting tools for iron and steel, hand tools, threading dies for brass.

Temperature, 400 to 500° F.—Hand taps and dies, hand reamers, drills, bits, cutting dies, penknives, milling cutters, chasers, inserted sawteeth, press dies for sheet steel, rock drills, taps and dies, wire-drawing dies, dental and surgical instruments, twist drills.

Temperature, 500 to 600° F.—Bending and forming dies, shear blades, chuck jaws, forging dies, drifts, gages, press-dies, flat drills, reamers, chisels and tools for wood-cutting, hammers and drop dies, axes, lathe tools for copper augers, cold chisels, coppersmith tools, grinders, screw drivers, molding and planing tools, hacksaws, needles, butcher knives, saws and tools.

TENTATIVE SPECIFICATIONS
FOR
HIGH-SPEED TOOL STEEL[1]

Serial Designation: A 92 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1924

Material Covered. 1. (*a*) These specifications cover high-speed tool steels, the composition of which shall be as agreed upon by the purchaser and vendor, with the permissible variations specified in Section 4.

(*b*) These tool steels are suitable for lathe and planer tools, milling cutters, drills, etc.

I. MANUFACTURE

Process. 2. The tool steel shall be made either by the crucible or electric furnace process.

Annealing and Hardness. 3. The steel shall be furnished annealed unless otherwise specified. The microstructure, Brinell hardness and fracture tests shall be as agreed upon between the vendor and the purchaser.

II. CHEMICAL PROPERTIES AND TESTS

Chemical Composition 4. The composition of the tool steels shall be as agreed upon by the purchaser and vendor with the following permissible variations in composition:

	Permissible Variations, per cent	
	Over	Under
Carbon	0.05	0.05
Manganese	0.15	0.15
Phosphorus	0.01	....
Sulfur	0.01	....
Silicon	0.15	0.15
Chromium	0.50	0.50
Vanadium	0.25	0.25
Tungsten	0.75	0.75
Cobalt	0.50	0.50

Other elements as agreed.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. G. H. Woodroffe, Secretary of Committee A-1 on Steel, Parkesburg Iron Co., Parkesburg, Pa.

Method of Sampling. 5. (*a*) Milled samples for analysis shall be taken from the sample bar to represent the full cross-section, or drillings shall be taken by drilling a bar midway between the center and the surface, parallel to the axis of the bar. In either case the decarburized material shall be rejected.

(*b*) In general, the minimum depth to which the surface shall be removed before a sample is taken shall be in accordance with the following requirements:

THICKNESS OR DIAMETER, IN.	MATERIAL REMOVED, IN.
1 or under	$\frac{1}{32}$
Over 1 to $2\frac{1}{2}$, inclusive	$\frac{1}{16}$
Over $2\frac{1}{2}$ to 4, inclusive	$\frac{1}{8}$
Larger sizes	As agreed

(*c*) In the case of drill rod and other material of similar finish where freedom from decarburization is specified, samples shall be taken from the surface in addition to the methods described in Paragraph (*a*).

Standard Methods of Analysis. 6. In case of dispute, the chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[1]

III. MANUFACTURING TOLERANCES IN DIMENSIONS

Manufacturing Tolerances in Dimensions. 7. Variations in cross-sectional dimensions of the material shall not exceed the following amounts:

FORGED AND ROLLED MATERIAL

	PERMISSIBLE VARIATIONS, IN.	
	OVER	UNDER
$\frac{1}{2}$ in. or under	0.010 ($\frac{1}{100}$)	0.010 ($\frac{1}{100}$)
Over $\frac{1}{2}$ in. to 1 in., inclusive	0.015 ($\frac{1}{64}$)	0.015 ($\frac{1}{64}$)
Over 1 in. to $1\frac{1}{2}$ in., inclusive	0.031 ($\frac{1}{32}$)	0.031 ($\frac{1}{32}$)
Over $1\frac{1}{2}$ in. to 2 in., inclusive	0.046 ($\frac{3}{64}$)	0.031 ($\frac{1}{32}$)
Over 2 in. to 4 in., inclusive	0.125 ($\frac{1}{8}$)	0.031 ($\frac{1}{32}$)
Over 4 in. to 6 in., inclusive	0.156 ($\frac{5}{32}$)	0.031 ($\frac{1}{32}$)
Over 6 in. to 8 in., inclusive	0.188 ($\frac{3}{16}$)	0.063 ($\frac{1}{16}$)
Over 8 in.	0.250 ($\frac{1}{4}$)	0.063 ($\frac{1}{16}$)
FINISHED MATERIAL (DRILL ROD)		
$\frac{7}{16}$ in. and under	0.0005	0.0005
Over $\frac{7}{16}$ in.	0.001	0.001

IV. FINISH

Finish. 8. (*a*) The material shall be free from injurious defects and shall have a workmanlike finish.

(*b*) All drill rods shall be coated with a rust preventive.

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[1] 1924 Book of A.S.T.M. Standards.

V. MARKING

Marking. 9. (*a*) Identification marks shall be stamped on the material as agreed by the vendor and the purchaser. All identification marks shall be about ¼ in. in height when the size permits.

(*b*) In lieu of marking as specified in Paragraph (*a*), the ends of the bars and rods may be painted as agreed by the vendor and the purchaser.

Bundling Small Sizes. 10. All rods and bars of which the largest cross-sectional dimension is ⅜ in. or less shall be boxed or bundled, each box or bundle to contain bars or rods of the same size, shape and class of material. A metal tag shall be securely attached to the wrapping wire or box. Rods and bars of cross-sectional dimensions exceeding ⅜ in. and not exceeding 1½ in., where convenient to vendor and purchaser, may be bundled and marked as specified above. Bundles shall be of suitable size to permit easy handling and shall be securely fastened.

VI. INSPECTION AND REJECTION

Inspection. 11. The vendor shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Comparison with Selective Sample. 12. The steel shall correspond in quality and characteristics to the samples submitted under the specifications and approved by the purchaser.

Rejection. 13. Material which does not conform to the chemical composition and specified dimensional variations, or which at any time shows injurious defects inherent in the steel, will be rejected and the vendor shall be notified.

APPENDIX

TENTATIVE RECOMMENDED PRACTICE IN THE HEAT TREATMENT OF 18-PER-CENT TUNGSTEN HIGH-SPEED STEEL[1]

General.—This specification covers the process to be followed in heat treating high-speed steel.

Process.—Operations:

1. Heating for annealing.
2. Cooling.
3. Heating for hardening—(*a*) Preheating—(*b*) Heating for quenching.
4. Quenching.
5. Drawing for secondary hardness.

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[1] This is a tentative Recommended Practice approved by the Standards Committee of the American Society for Steel Treating and is published by permission of that Society.

1. *Heating for Annealing.*—Heat slowly and uniformly to a temperature of 1600° F. (871° C.) and hold for complete refinement.

2. *Cooling.*—Cool in furnace, infusorial earth, mica, lime or any medium, that will permit of uniform slow cooling.

3. *Heating for Hardening.*—(*a*) Preheating—Heat slowly and uniformly to 1500° F. (816° C.) in a furnace of sufficient size.

(*b*) Heating for Quenching—Transfer preheated steel to a high-temperature furnace that is maintained at a temperature of 2250° F. to 2400° F. (1232 to 1315° C.), depending on the type of tools being hardened.

In order to obtain the most satisfactory "red hardness" conditions, the steel should be brought rapidly to the higher temperature; but in many cases the character of the cutting edges of certain form tools, such as milling cutters, threading tools, etc., makes it inadvisable to use the higher temperatures owing to destruction of the delicate edges through blistering, pitting, etc. It is, therefore, usual to use the higher temperatures for tools such as rough lathe tools, while the finer class of tools is hardened at the lower temperatures.

High-speed steel tools should not be held at the high heat longer than necessary, since holding at the high hardening temperatures required causes excessive grain growth, with subsequent brittleness of the hardened tools.

Tools that cannot be ground after hardening are often heated in a barium chloride, or some such suitable bath.

4. *Quenching.*—Quench the steel in oil, or air, from the hardening temperature. It is advisable to maintain the oil quenching bath at a temperature of 150 to 200° F. (65 to 93° C.) to eliminate possibility of breakage with intricately shaped tools.

5. *Drawing for Secondary Hardness.*—Reheat uniformly in an open furnace, or preferably in a salt ($NaNO_3$) or lead bath, to 1050 to 1150° F. (565 to 631° C.) for a sufficient length of time, and cool in air, or oil, as preferred.

NOTES ABOUT THE PROCESS

Cooling from Annealing.—Cooling in air should not be permitted, since air cooling from the annealing temperature is apt to result in partial hardening of the tool.

Heating for Hardening.—It is the customary practice to always preheat for hardening in an open furnace, since preheating in a salt bath causes the salt to adhere to the tool, and the subsequent high temperature treatment causes unusual corroding from the adhering salt. Even preheating in lead is objectionable from small quantities of adhering lead. There is not much advantage to be gained in using a molten bath for the preheating, since the preheating temperature may vary over the comparatively wide range of 1400 to 1600° F., and an open furnace is invariably used in practice.

Quenching from Drawing Temperatures.—This should be optional with the steel treater, as quenching from the drawing temperature does not give increased toughness over samples that have air cooled. Evidently the increased toughness resulting when carbon or chrome-vanadium steels are quenched from drawing temperatures of 700 to 1000° F. does not apply to high-speed steels, as impact tests on oil-cooled and air-cooled samples show no difference in favor of the oil-cooled pieces.

TENTATIVE SPECIFICATIONS
FOR
HOT-DIPPED GALVANIZED SHEETS[1]

Serial Designation: A 93 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Scope. 1. These specifications cover hot-dipped bessemer steel, open-hearth steel, open-hearth iron and wrought-iron sheets of three classes, as follows:

Class A—Flat or corrugated sheets that are not intended to be formed.

Class B—Flat or corrugated sheets to be curved to a large radius.

Class C—Flat sheets for miscellaneous purposes.

I. CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 2. These specifications contain no detailed requirements for the chemical composition of the base metal. If base metal containing copper is specified, it shall conform to the following requirements:

Copper, minimum.................................. 0.20 per cent

Check Analysis. 3. An analysis of copper-bearing sheets may be made by the purchaser from the test specimen specified in Section 6. The copper content thus determined shall conform to the requirement specified in Section 2.

Zinc Coating. 4. (*a*) The weight of the zinc coating shall conform to the requirements specified in Table I, the average being taken of the chemical determination from three specimens $2\frac{1}{4}$ in. square cut from the ends and middle of the sheet as specified in Section 7; provided, however, that the coating on any one the three specimens shall be at least 75 per cent of the minimum average weight of coating specified in Table I.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. James Aston, Secretary of Committee A-5 on Corrosion of Iron and Steel, A. M. Byers Co., Pittsburgh, Pa.

(*b*) The weight of the zinc coating shall be determined by the basic lead acetate, hydrochloric acid - antimony chloride or sulfuric-permanganate method.

(*c*) The weight of coating specified in Table I is the total coating on both sides of a sheet 1 ft. square, the numerical value of which in ounces is the same as that determined in grams from a sample $2\frac{1}{4}$ in. square.

II. PHYSICAL PROPERTIES AND TESTS

Bend Tests. 5. (*a*) *Base Metal Tests.*—Any portion of the test specimen specified in Section 6 shall bend cold through 180 deg. flat on itself without fracture of the base metal. For steel, the bend may be made in any direction; for wrought iron the line of the bend shall be transverse to the direction of the rolling of the sheet.

TABLE I.—WEIGHT OF COATING

Galvanized Sheet Gage	Minimum Average Weight of Coating, oz. per sq. ft. Class A	Class B	Class C
No. 8	2.50	2.00	1.75
No. 9	2.50	2.00	1.75
No. 10	2.50	2.00	1.75
No. 11	2.50	2.00	1.75
No. 12	2.50	2.00	1.75
No. 14	2.50	2.00	1.75
No. 16	2.50	2.00	1.75
No. 18	2.50	2.00	1.50
No. 20	2.50	2.00	1.50
No. 22	2.50	2.00	1.50
No. 24	....	2.00	1.30
No. 26	....	2.00	1.10
No. 27	....	2.00	1.10
No. 28	....	1.80	1.10
No. 29	....	1.60	1.10
No. 30	....	1.40	1.10

(*b*) *Coating Tests.*—Sheets of Class *A* material shall stand corrugating without flaking or cracking of the coating. Sheets of Class *B* material shall stand corrugating and also subsequent longitudinal curving, as given below, without flaking or cracking of the coating.

Gage	Diameter of Circle
No. 12	36 in.
No. 14	21 "
No. 16	12 "

In the case of sheets of Class *C* material, any portion of the test specimen specified in Section 6, of sheets lighter than No. 16 gage, shall stand bending in any direction without flaking of the coating on either side when bent through 180 deg. over four thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend tests.

Test Specimens. 6. Three specimens exactly $2\frac{1}{4}$ in. square shall be cut to represent each test sheet, one being cut from the center of the sheet and the others from diagonally opposite corners, but at least 4 in. from the end and 2 in. from the side of the sheet.

Number of Tests. 7. (*a*) One each of the tests specified shall be made from one sheet in each lot of 1000 sheets or fraction thereof of each gage of each lot offered for inspection.

(*b*) If any sheet fails to meet the requirements of these specifications, a retest will be allowed from two other sheets in the same lot, both of which shall meet the requirements.

III. PERMISSIBLE VARIATIONS

Dimensions. 8. The sheets shall conform to the dimensions specified with the following permissible variations:

(*a*) The width shall be not less than that ordered, but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall be not less than that ordered, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof above 96 in., the permissible variation may be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "to be re-squared."

Weight. 9. The average weight per square foot of the galvanized sheets as determined by the weighing of lots not exceeding 6000 lb. shall conform to the requirements specified in Table II, which are based on a maximum variation from the nominal weight of 5 per cent for gages Nos. 8 to 16, inclusive, and $3\frac{1}{2}$ per cent for gages thinner than Nos. 16 to 22, inclusive, and $2\frac{1}{2}$ per cent for gages thinner than No. 22.

IV. FINISH

Finish. 10. The finished sheets shall be of first-class commercial quality, free from flaws or mechanical defects such as pin holes, cracks, blisters, and blackened sal-ammoniac or acid spots.

V. MARKING

Marking. 11. The top sheet in each bundle, the top sheet in each lot or a number of sheets when shipped loose shall legibly show the name and brand of the manufacturer, class, gage and size.

VI. INSPECTION AND REJECTION

Inspection. 12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) The purchaser may make the tests and inspection to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests and inspection shall be made at the expense of the purchaser.

Table II.—Weights of Galvanized Sheets

Galvanized Sheet Gage	Weight of Galvanized Sheets, All Classes, oz. per sq. ft.		
	Minimum	Nominal	Maximum
No. 8	106.9	112.5	118.1
No. 9	97.4	102.5	107.6
No. 10	87.9	92.5	97.1
No. 11	78.4	82.5	86.6
No. 12	68.9	72.5	76.1
No. 14	49.9	52.5	55.1
No. 16	40.4	42.5	44.6
No. 18	33.3	34.5	35.7
No. 20	25.6	26.5	27.4
No. 22	21.7	22.5	23.3
No. 24	18.0	18.5	19.0
No. 26	14.1	14.5	14.9
No. 27	13.2	13.5	13.8
No. 28	12.2	12.5	12.8
No. 29	11.2	11.5	11.8
No. 30	10.2	10.5	10.8

Rejection. 13. (*a*) Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected.

(*b*) Sheets which, subsequent to tests and inspection at the mill or elsewhere and their acceptance, show blackened sal-ammoniac or acid spots, improper galvanizing, improper trimming or other defects for which the manufacturer is responsible, will be rejected and shall be replaced by the manufacturer.

Rehearing. 14. Samples tested in accordance with Section 7 (*a*) which represent rejected material, shall be preserved for two weeks from the date of the test report.

TENTATIVE SPECIFICATIONS
FOR
PHOSPHOR TIN[1]

Serial Designation: B 51 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1924.

Material Covered.

1. These specifications cover phosphor tin in one grade.

I. MANUFACTURE

2. The manufacturer shall use new tin of uniform quality throughout in the manufacture of phosphor tin.

3. The manufacturer or vendor shall furnish phosphor tin ingots in the form of notched slabs of a size that can be handled conveniently.

4. Phosphor tin shall be clean, free from defects, and uniform in quality.

II. CHEMICAL PROPERTIES AND TESTS

(*A*) *Chemical Composition*

5. The material shall conform to the following requirements as to chemical composition:

Phosphorus, minimum	3.50 per cent
Phosphorus plus tin, minimum	99.50 "

(*B*) *Sampling and Testing*

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled completely through or one-half through from top to bottom, the surface material being rejected.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

III. MARKING

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat may be identified. Marking may be done either by stamping or painting.

IV. CLAIMS

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight of metal meeting specifications.

TENTATIVE SPECIFICATIONS
FOR
PHOSPHOR COPPER[1]

Serial Designation: B 52 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

1. Under these specifications phosphor copper is considered in two grades.

I. MANUFACTURE

2. The manufacturer shall use new metal, or new metal and scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

3. The manufacturer or vendor shall furnish phosphor copper as ingots in the form of notched slabs, weighing from 15 to 20 lb., unless otherwise specified in the contract.

4. Phosphor copper shall be clean, free from defects and uniform in quality.

II. CHEMICAL PROPERTIES AND TESTS

(A) Chemical Composition

5. The material shall conform to the following requirements as to chemical composition:

	PHOSPHORUS, MINIMUM, PER CENT	PHOSPHORUS PLUS COPPER, MINIMUM, PER CENT	IRON, MAXIMUM, PER CENT
Grade A	14.0	99.75	0.15
Grade B	10.0	99.75	0.15

(B) Sampling and Testing

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

shall be drilled completely through or one-half through from top and bottom, the surface material being rejected.

III. MARKING

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat may be identified. Marking may be done either by stamping or painting.

IV. CLAIMS

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight meeting specifications.

TENTATIVE SPECIFICATIONS
FOR
SILICON COPPER[1]

Serial Designation: B 53 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

1. These specifications cover silicon copper in one grade.

I. MANUFACTURE

2. The manufacturer shall use new metal, or new metal and scrap resulting from the manufacture of ingots of similar composition in the manufacture of this material.

3. The manufacturer or vendor shall furnish silicon copper in the form of ingots or notched slabs of such size that they can be handled conveniently.

4. Silicon copper shall be clean, free from defects, and uniform in quality.

II. CHEMICAL PROPERTIES AND TESTS

(*A*) *Chemical Composition*

5. The material shall conform to the following requirements as to chemical composition:

Silicon	10 to 12 per cent
Tin, maximum	0.25 "
Zinc, maximum	0.25 "
Iron, maximum	0.75 "
Aluminum, maximum	0.25 "
Copper	Remainder

The sum of the copper, silicon and iron content shall be not less than 99.4 per cent.

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(*B*) *Sampling and Testing*

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled completely through or one-half through from top and bottom, the surface material being rejected.

III. MARKING

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat may be identified. Marking may be done either by stamping or painting.

IV. CLAIMS

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight of metal meeting specifications.

TENTATIVE SPECIFICATIONS
FOR
LIGHT ALUMINUM CASTING ALLOYS[1]

Serial Designation: B 26 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered.

1. These specifications cover commercial light alloys of aluminum having a specific gravity of 3 and less.

I. MANUFACTURE

Process.

2. The alloy may be made by any approved method.

II. CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The following alloys are described by these specifications; they shall conform to the following requirements as to chemical composition:

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Manganese, per cent	Zinc, per cent	Remarks
A.....	not under 96.5	1 to 1.5	not over 0.5	not over 0.5	trace	0.7 to 2.0	trace	
B.....	not under 92.5	not over 0.6	not over 1.0	4.5 to 6.0	trace	not over 0.2	not over 0.20	
C.....	not under 90.0	7 to 8.5	......	......	......	......	not over 0.20	Total of Fe, Si, Mn, Zn and Sn not to exceed 1.70 per cent.
D.....	88 to 92	6 to 8.0	not over 1.50	......	......	......	not over 2.50	Total of Si, Mn, and Sn not to exceed 1.00 per cent.

Sampling.

4. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

These Tentative Specifications, when adopted as standard, will supersede the present Standard Specifications for Light Aluminum Casting Alloys (Serial Designation: B 26 – 21), 1924 Book of A.S.T.M. Standards.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawdust or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

III. PHYSICAL PROPERTIES AND TESTS

Tension Tests. 5. The alloys shall conform to the following minimum requirements as to tensile properties:

Alloy	Minimum Tensile Strength, lb. per sq. in.	Minimum Elongation in 2 in., per cent
A	18 000	8
B	16 000	3.5
C	18 000	..
D	18 000	..

Test Specimens. 6. (*a*) Two test bars of the form and dimensions shown in Fig. 1 shall be an integral part of large castings, or cast separately in the case of small castings to represent a lot or melt, and shall be molded in a manner similar to the castings which they represent. If the castings are heat treated, the test bars representing such castings shall be similarly heat treated.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

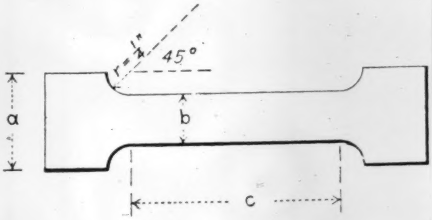
Number of Tests. 7. (*a*) Tests shall as far as possible be made by heats or melts, but unless otherwise agreed, two tension tests shall be made upon each unit lot of 500 lb. or single delivery of less than 500 lb.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

IV. INSPECTION AND REJECTION

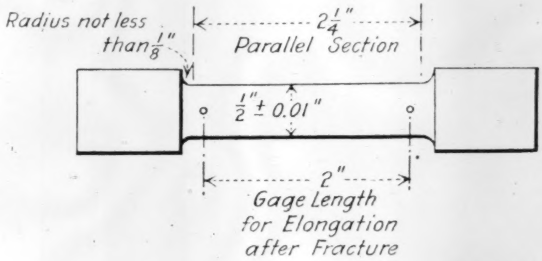
Inspection. 8. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



a ---- 1 in.
b --- not greater than 5/8 in., nor less than 1/2 in.
c --- not less than 2 1/8 in.

FIG. 1


Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2

9. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer free of charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer. **Rejection.**

EXPLANATORY NOTES

These alloys are all suitable for general sand casting purposes.

The Naval Gun Factory has been the largest user of Alloy A. Its resistance to salt-water corrosion makes it suitable for marine equipment. Although very large castings have been successfully poured from it, Alloy A is generally regarded as difficult to handle in the foundry. Its proportional limit is rather low.

Alloy B possesses very good foundry characteristics; the melt is quite fluid and the solidification shrinkage is low. It is especially suitable for the production of dense non-porous castings and of intricate shapes containing both heavy and thin sections. This alloy is the most resistant to corrosion of all the commonly used aluminum casting alloys. It is somewhat more difficult to machine than the other alloys and, as in the case of Alloy A, possesses a rather low proportional limit.

Alloys C and D are similar, both being substantially aluminum-copper alloys. The composition limits are such that secondary metal can be used in the manufacture of Alloy D. While no lower limits are placed on the iron and zinc in Alloy D, it is assumed they will be present and they are stated to improve the machining qualities of the castings.

The pattern maker's shrinkage is usually taken as 0.156 in. per foot for all these alloys. The weight lies within the range of 0.096 lb. per cu. in. for Alloy B, and 0.103 lb. per cu. in. for Alloy C, corresponding to the specific gravities 2.66 and 2.85, respectively. These are approximate values, since the weights will vary with the actual compositions of the individual samples.

Section 5.—The elongations of Alloys C and D are usually so low as to present difficulties in their accurate measurement. The fact that a very large percentage of all aluminum castings produced in this country is made from these alloys, is evidence that the low elongation is not indicative of excessive brittleness.

Section 6.—Some latitude has been allowed in the diameter of the cast test bars; test bars cast to size are stronger than those which are machined, and the tensile properties specified can be obtained under usual conditions only with the cast-to-size bar.

It is strongly recommended that a self-centering form of tension test specimen holder be used. Most aluminum alloys are brittle and give lower and less uniform test results when tested in ordinary wedge grips without centering.

TENTATIVE SPECIFICATIONS
FOR
MANGANESE-BRONZE INGOTS FOR SAND CASTINGS[1]

Serial Designation: B 7 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision

ISSUED, 1924

1. These specifications cover the copper-zinc alloy known commercially as manganese bronze. **Material Covered.**

I. MANUFACTURE

2. The bronze shall be cast in the form of ingots having notched flat bottoms, approximately 3 by 2¾ in. wide by 12 in. long, properly tapered to strip easily from an iron mold. **Size of Ingots.**

II. CHEMICAL PROPERTIES

3. The bronze shall conform to the following requirements as to chemical composition: **Chemical Composition.**

	MAXIMUM	MINIMUM
Copper, per cent	60	55
Zinc, per cent	42	38
Tin, per cent	1.5	0.0
Manganese, per cent	3.5	0.0
Aluminum, per cent	1.5	0.0
Iron, per cent	2.	0.0
Lead, per cent	0.2	0 0

III. PHYSICAL PROPERTIES AND TESTS

4. The bronze shall conform to the following minimum requirements as to tensile properties: **Tension Tests.**

Tensile strength	70,000 lb. per sq. in.
Elongation in 2 in.	30 per cent

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

These Tentative Specifications are in effect a revision of the Standard Specifications for Manganese-Bronze Ingots for Sand Castings. The Standard Specifications, which were last published under the Serial Designation: B 7 - 14, have accordingly been withdrawn.

Tension Test Specimens. 5. (*a*) The tension test specimen shall be cut from one corner near the bottom of the test ingot.

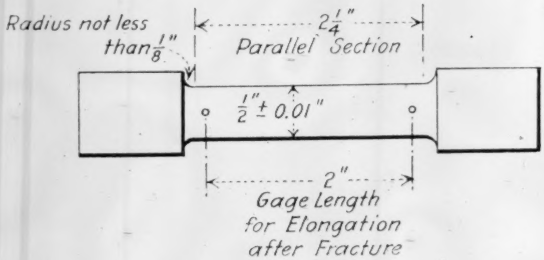
(*b*) The specimen shall conform to the dimensions shown in Fig. 1.

Number of Tests. 6. (*a*) One test ingot shall be selected by the inspector to represent 10,000 lb. of ingots or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case two additional test specimens may be selected by the inspector from the same lot, and tested to represent the lot.

IV. MARKING

Marking. 7. Each ingot shall be stamped with its proper heat or charge number.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

V. INSPECTION AND REJECTION

Inspection. 8. (*a*) Inspection may be made at the manufacturer's works where the castings are made or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 9. (*a*) If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 or 4, all ingots in such lot will be rejected, irrespective of the heat or heats from which the test ingots are selected.

TENTATIVE SPECIFICATIONS
FOR
MANGANESE-BRONZE SAND CASTINGS[1]

Serial Designation: B 54 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1924

Material Covered.

1. These specifications cover castings made from the copper-zinc alloy known commercially as manganese bronze.

I. MANUFACTURE

Material Used.

2. Material used in these castings shall conform to the requirements of the Tentative Specifications for Manganese-Bronze Ingots for Sand Castings (Serial Designation: B 7 – 24 T) of the American Society for Testing Materials.[2] At least 35 per cent of the mixture shall consist of ingots manufactured in accordance with the Tentative Specifications for Manganese-Bronze Ingots and the remainder shall consist of risers, sprues, and defective castings, accruing from the manufacture of castings in accordance with these specifications. Zinc additions shall be of zinc conforming to the requirements of Grade 2 or better of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[3]

II. CHEMICAL PROPERTIES

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

	Maximum	Minimum
Copper, per cent	60	55
Zinc, per cent	42	38
Tin, per cent	1.5	0.0
Manganese, per cent	3.5	0.0
Aluminum, per cent	1.5	0.0
Iron, per cent	2.	0.0
Lead, per cent	0.4	0.0

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

[2] See p. 789.

[3] 1924 Book of A.S.T.M. Standards.

III. PHYSICAL PROPERTIES AND TESTS

Tension Tests. 4. The bronze should conform to the following minimum requirements as to tensile properties:

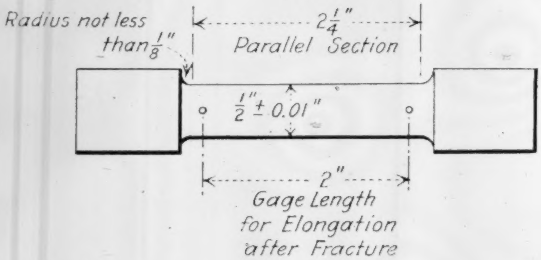
Tensile strength	65,000 lb. per sq. in.
Elongation in 2 in	25 per cent

Tension Test Specimen. 5. (*a*) The tension test specimen shall be machined from coupons to the dimensions as shown in Fig. 1.

(*b*) The coupon attached to the castings shall be in accordance with Fig. 2, unless special authority to use coupons of other forms and dimensions is obtained from the purchaser.

(*c*) Each casting weighing 250 lb. or more as delivered from the foundry shall have at least two test coupons cast attached.

(*d*) When the castings constituting a heat weigh less than 250 lb. each, one coupon shall be cast attached to the first and one to the last casting poured in each heat.



Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial

FIG. 1.—Test Specimen.

(*e*) Castings which are too small to permit the casting of a coupon attached shall, when possible, be represented by coupons cast in the same flask and gated to the castings or runners. One coupon shall be cast gated to the first and one to the last casting poured in the heat.

(*f*) Only in cases when it is impossible to cast coupons in the same flask with small castings shall such coupons be cast separately. In case it is necessary to cast coupons separately, one coupon shall be cast to the first of the heats and one to the last.

(*g*) At least two ounces of drillings from each coupon tested shall be forwarded for chemical analysis.

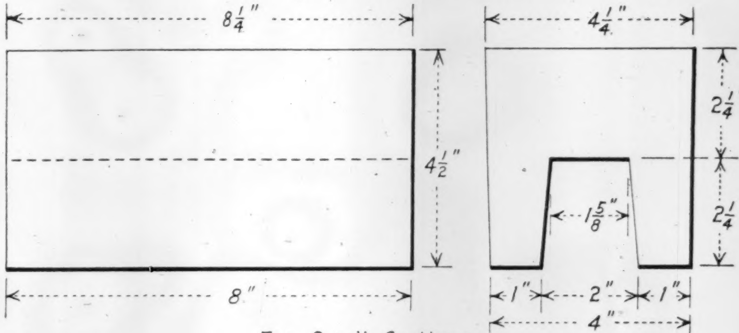
IV. MARKING

Marking. 6. Each casting shall be clearly stamped with the heat number, and the heat number shall also be stamped on the test coupon representing that heat.

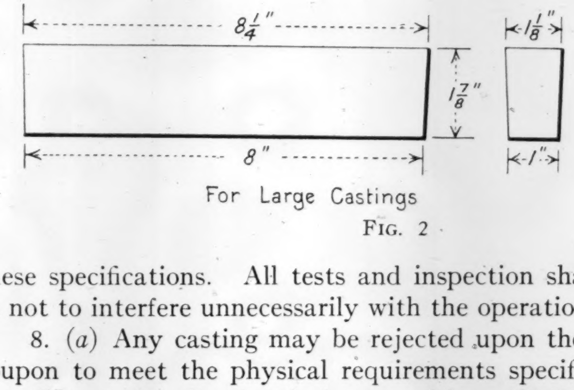
V. INSPECTION AND REJECTION

Inspection. 7. (*a*) Inspection may be made at the manufacturer's works where the castings are made or at the point at which they are received at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



For Small Castings.



For Large Castings

FIG. 2

Rejection. 8. (*a*) Any casting may be rejected upon the failure of the test coupon to meet the physical requirements specified or for the noncompliance with the chemical composition. If the physical or chemical tests indicate that the heat of castings represented by its test coupon does not conform to the physical or chemical requirements, or both, the entire heat shall be rejected.

(*b*) In case tests on the first test piece do not conform to these specifications, a second test piece shall be tested. If such a test on the second piece is thoroughly satisfactory the castings or heat shall be accepted; if unsatisfactory, the castings or heat shall be rejected.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS 70-30 BRASS CONDENSER TUBES AND FERRULE STOCK[1]

Serial Designation: B 55 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover seamless tubes and ferrule stock made from 70-30 brass for condenser use.

I. MANUFACTURE

Process. 2. The tubes shall be cold drawn to size from an alloy made from lake or electrolytic copper, conforming to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5) of the American Society for Testing Materials,[2] and zinc of Grade No. 1 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[2] Scrap shall not be used except such as may result from the manufacture of articles of the same composition.

Annealing. 3. (*a*) Condenser tubes shall be annealed sufficiently to enable the tubes to pass the physical and metallographic tests herein specified.

(*b*) Tubes for ferrule stock shall be sufficiently annealed to prevent cracking, but they need not be held within the close limits specified for condenser tubes.

II. CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The material shall conform to the following requirements as to chemical composition:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

Copper	not less than 70.00 per cent
Lead	not over 0.075 "
Iron	not over 0.06 "
Zinc	remainder

Sampling. 5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from at least three separate tubes from each lot of 600 tubes or less, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS

Microscopic Examination. 6. (*a*) A microscopic examination of the tubes shall show sufficient annealing for complete recrystallization with a uniform grain size not in excess of 0.045 mm. in average diameter, the grain size approaching as closely as possible a mean diameter of not over 0.035 mm. (Note 1).

(*b*) The determination of grain size shall be made by comparison of micrographs representing the samples with micrographs of standard specimens for which the grain size has been accurately determined. The magnification in all such micrographs shall be 75 diameters. The standard micrographs shall be taken from specimens the grain size of which has been determined by Jeffries' method for grain size measurements as described in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys (Serial Designation: E 2) of the American Society for Testing Materials[1] at a magnification of 250 diameters. Reproductions of micrographs so prepared are appended hereto.

Hammering Test. 7. The tubes shall be capable of withstanding the following test without showing cracks or flaws: Pieces cut from the ends of the tubes shall be hammered flat on different elements throughout their length so that a gage set at 3 times the thickness of the metal shall pass over the tube freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Expanding Test. 8. The tubes shall be capable of withstanding the following test without showing signs of cracking or rupture: A pin having a taper of 1½ in. per foot shall be driven into the tube until the diameter has been increased 20 per cent.

Strain Test. 9. A test specimen 6 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking (Note 2).

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[1] 1924 Book of A.S T.M. Standards.

Hydrostatic Test. 10. All tubes shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. without leakage and shall show no sign of strain or cracking (Note 3).

Number of Tests. 11. Tubes shall be grouped into lots of 600 tubes or less. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 9, inclusive.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter. 12. The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

Nominal Diameter, in.	Permissible Variation, in.
Up to 0.500, inclusive	±0.002
Over 0.500 to 0.740, inclusive	±0.0025
Over 0.740 to 1.000, inclusive	±0.003
Over 1.000 to 1.250, inclusive	±0.0035
Over 1.250 to 1.500, inclusive	±0.004

Thickness. 13. No tube at its thinnest point shall be less than the thickness specified.

Length. 14. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.).

Weight. 15. No single tube that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.308 lb.

V. WORKMANSHIP AND FINISH

Workmanship. 16. The tubes shall be round, straight and of uniform thickness throughout. They shall be free from cracks, seams, slivers, scale and other surface defects both inside and outside.

Finish. 17. All tubes shall be acid cleaned after the final annealing.

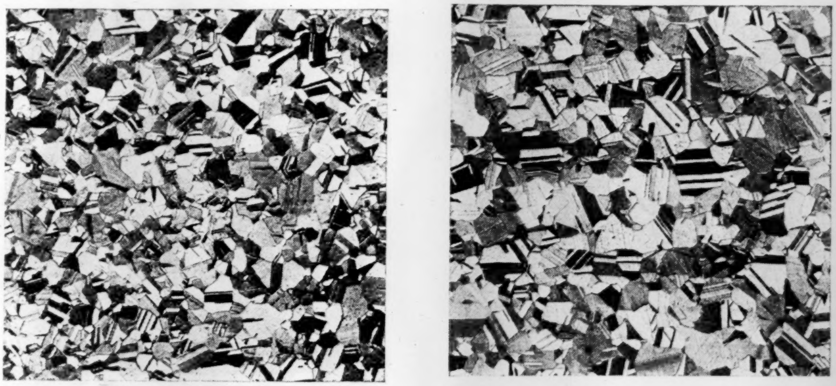
VI. INSPECTION AND REJECTION

Retest. 18. If any test specimen representing a lot fails to meet the requirements of Section 4 and Sections 6 to 8, inclusive, two additional specimens, at the option of the manufacturer, may be taken as before and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

Inspection. 19. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

EXPLANATORY NOTES

NOTE 1.—The so-called "Compression Test" requiring that tubes of varying sizes and thicknesses should be subjected to certain arbitrary pressures without more than 0.005 in. permanent deformation has not been included because the physical properties of the tube under compression are functions of the temperature at which it receives its final heat treatment and the metallographic examination sufficiently indicates the temper of the tube to decide whether it may be properly packed in the condenser head.



(*a*) Mean Crystal Diameter 0.035 mm. (× 75).

(*b*) Mean Crystal Diameter 0.045 mm. (× 75).

FIG. 1.—Microstructure of 70-30 Brass, Etched with NH_4OH, H_2O_2.

Until concrete information is available relative to the effect of grain size on corrosion, the committee points out that Section 6 (*a*) has been prepared solely for the purpose of getting a measurement of the compressibility and freedom from stress.

NOTE 2.—Since the specifications require that the tubes shall be annealed sufficiently to establish crystallin equilibrium and show a grain size within certain definite limits, it would seem that a test for internal strains might be unnecessary. The mercurous nitrate test has been included, however, to guard against the hardening of tubes by light drawing operations which would not deform the crystals to an extent recognizable by microscopic examination.

NOTE 3.—Provision is made for the testing of each tube separately to 1000 lb. per sq. in. hydrostatic pressure in order to develop and make evident fractures or punctures which may have occurred in the process of manufacture.

This is a 100 per cent test and it is not necessary to again test all the tubes by subjecting them to 80 lb. per sq. in. pneumatic pressure while immersed in water. Both of these tests are made to detect the same kind of faults and either, if carried out according to the intent of the specifications, should be sufficient. The 1000-lb. hydrostatic pressure test is the more searching and has been specified. The multiplication of tests to determine the same facts under the plea that there may be carelessness in applying one or another should not be encouraged.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS MUNTZ METAL CONDENSER TUBES AND FERRULE STOCK[1]

Serial Designation: B 56 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover seamless tubes and ferrule stock made from Muntz metal for condenser use.

I. MANUFACTURE

Process. 2. The tubes shall be made by any approved process, and finished by cold drawing, from an alloy made from lake or electrolytic copper, conforming to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5) of the American Society for Testing Materials[2] and Zinc of Grades Nos. 1, 2, or 3 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[2] Scrap of equivalent grades may be used.

Annealing. 3. The tubes and ferrule stock shall be annealed sufficiently to enable the tubes to pass the metallographic and physical tests herein specified, and shall be suitable for packing in tube plates.

II. CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The material shall conform to the following requirements as to chemical composition:

Copper	59.00 to 63.00 per cent
Lead	not over 0.30 "
Iron	not over 0.07 "
Zinc	remainder

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

Sampling. 5. The sample of chemical analysis shall consist of drillings, millings, or clippings taken from at least three separate tubes from each lot of 600 tubes or less, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS

Microscopic Examination. 6. The tubes shall have been so annealed that, when magnified to 75 diameters, a properly prepared specimen shall show uniform and complete recrystallization.

Hammering Test. 7. The tubes shall be capable of withstanding the following test without showing cracks or flaws: Pieces cut from the remainder of the test tubes shall be hammered flat on different elements throughout their length so that a gage set at 3 times the thickness of the metal shall pass over the tube freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Expanding Test. 8. The tubes shall be capable of withstanding the following test without showing signs of cracking or rupture: A pin having a taper of $1\frac{1}{2}$ in. per foot shall be driven into the tube until the diameter has been increased 15 per cent.

Strain Test. 9. A test specimen 6 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking.

Hydrostatic Test. 10. All tubes shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. without leakage and shall show no sign of strain or cracking.

Number of Tests. 11. Tubes shall be grouped into lots of 600 tubes or less. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 9, inclusive.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter. 12. The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

NOMINAL DIAMETER, IN.	PERMISSIBLE VARIATION, IN.
Up to 0.500, inclusive	±0.002
Over 0.500 to 0.740, inclusive	±0.0025
Over 0.740 to 1.000, inclusive	±0.003
Over 1.000 to 1.250, inclusive	±0.0035
Over 1.250 to 1.500, inclusive	±0.004

13. No tube at its thinnest point shall be less than the thickness specified. **Thickness.**

14. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.). **Length.**

15. No single tube that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.306 lb. **Weight.**

V. WORKMANSHIP AND FINISH

16. All tubes shall be round, straight and free from cracks, seams, slivers, scale and other defects, both inside and outside. **Workmanship.**

17. All tubes shall be acid cleaned after the final annealing. **Finish.**

VI. INSPECTION AND REJECTION

18. If any test specimen representing a lot fails to meet the requirements of Section 4 and Sections 6 to 8, inclusive, two additional specimens, at the option of the manufacturer, may be taken as before and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified. **Retest.**

19. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

TENTATIVE SPECIFICATIONS
FOR
QUICKLIME FOR STRUCTURAL PURPOSES[1]

Serial Designation: C 5 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1921; REVISED, 1922, 1924

I. REQUIREMENTS

Requirements. 1. The quicklime shall conform to the following requirements as to chemical composition, calculated to the non-volatile basis:

	Calcium Lime	Magnesium Lime
Calcium oxide, minimum, per cent	75	..
Magnesium oxide, minimum, per cent	..	20
Calcium and magnesium oxides, minimum, per cent	95	95
Silica, alumina, and oxide of iron, maximum, per cent	5	5
Carbon dioxide, maximum, per cent		
(*a*) If sample is taken at the kiln	3	3
(*b*) If sample is taken at any other place	10	10

Percentage of Residue. 2. When tested in accordance with the method described in section 4, quicklime shall contain not more than 15 per cent by weight of residue.

II. METHODS OF TEST

Chemical Analysis. 3. The chemical analysis of the lime shall be made in accordance with the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 22 T) of the American Society for Testing Materials.[2]

Percentage of Residue. 4. An average $2\frac{1}{2}$-kg. (5-lb.) sample shall be put in a box of wood or of some material of similarly low thermal conductivity and slaked by an experienced operator with sufficient water at 70 to 80° F.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Quicklime. The Standard Specifications, which were last published under the Serial Designation: C 5-15, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 715 (1922).

(21 to 27° C.) to produce the maximum quantity of lime putty, care being taken to avoid "burning" or "drowning" the lime. It shall be allowed to stand for 1 hour and then washed through a No. 20 sieve by a stream of water having a moderate pressure. No material shall be rubbed through the sieve. The washing shall be continued until the residue on the screen appears to consist wholly of coarse particles, but in no case shall washing be continued more than 30 minutes. The residue shall be dried to constant weight at a temperature of 212 to 225° F. (100 to 107° C.). The sample of lump lime taken for this test shall be broken so as to all pass a 1-in. ring and be retained on a $\frac{1}{4}$-in. sieve. Pulverized lime shall be tested as received.

III. SAMPLING, RETESTING, PACKING AND MARKING

Sampling, Retesting, Packing, Marking.

5. The sampling, retesting, packing and marking shall be conducted in accordance with the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (Serial Designation: C 50 - 24 T) of the American Society for Testing Materials.[1]

APPENDIX

Quicklime can never be used as such for structural purposes; it must always be slaked first. Since the method of slaking is an important factor in determining the quality of the finished product, the following directions are given, not as a part of the specifications, but as information for the further protection of the purchaser.

PREPARATION OF LIME PUTTY

Directions for Slaking.

1. (*a*) *Introduction.*—Different kinds of lime vary considerably in the way in which they behave with water. A little supervision over the operation of slaking will amply pay for itself by insuring the production of the greatest possible quantity and the best possible quality of putty. To find out how to slake a new lot of lime, it is safest to try a little of it and see how it works. Since different lots of the same brand of lime vary somewhat, and since the weather conditions at the time have a decided influence, it is wise to try a sample from each lot used, whether familiar with the brand or not.

(*b*) *Classification of Limes.*—In a bucket, put two or three lumps of lime about the size of one's fist, or, in the case of granular lime, an equivalent amount. Add enough water to just barely cover the lime, and note how long it takes for slaking to begin. Slaking has begun when pieces split off from the lumps or when the lumps crumble. Water of the same temperature should be used for test and field practice.

If slaking begins in less than five minutes, the lime is quick slaking; from five to thirty minutes, medium slaking; over thirty minutes, slow slaking.

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[1] See p. 844.

(*c*) *Directions for Slaking.*—For quick-slaking lime, always add the lime to the water, not the water to the lime. Have enough water at first to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream, if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly, and add enough water to stop the steaming. Do not be afraid of using too much water with this kind of lime.

For medium-slaking lime, add the water to the lime. Add enough water so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add any more water than required, and not too much at a time.

For slow-slaking lime, add enough water to the lime to moisten it thoroughly. Let it stand until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water, but if this is not available, the mortar box may be covered in some way to keep the heat in.

Preparation of Putty for Use.

2. (*a*) *White Coat.*—After the action has ceased, run off the putty through a No. 10 sieve and store for a minimum of two weeks.

(*b*) *Base Coats.*—After the action has ceased, run off the putty through a No. 8 sieve. Add sand up to equal parts by weight, all of the hair required, and store for a minimum of two weeks.

(*c*) *Masons' Mortar.*—After the action has ceased, add part or all of the sand required, and store for a minimum of 24 hours.

TENTATIVE SPECIFICATIONS
FOR
QUICKLIME AND HYDRATED LIME FOR USE IN THE COOKING OF RAGS FOR THE MANUFACTURE OF PAPER.[1]

Serial Designation: C 45 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

Lime in the Cooking of Rags.

1. Rags are cooked for the manufacture of paper in a digester under steam pressure with lime or with lime and soda-ash. They are then washed to eliminate as much of the non-cellulose material as possible.

I. REQUIREMENTS.

Requirements.

2. (*a*) Either quicklime or hydrated lime may be used. It shall be clean and free from gritty substances.

(*b*) The standard composition for quicklime shall be a content of 90 per cent of available calcium oxide calculated on the basis of the weight of the sample taken at the point of manufacture.

(*c*) The standard composition for hydrated lime shall be a content of 85 per cent of available calcium hydroxide calculated on the basis of the weight of the sample taken at the point of manufacture.

II. METHODS OF TEST.

Chemical Analysis.

3. The chemical analysis of the lime shall be made in accordance with the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 22 T) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 715 (1922).

III. SAMPLING, INSPECTION, REJECTION, ETC.

Sampling, Inspection, Rejection, etc.

4. The sampling, inspection, rejection, retesting, packing and marking shall be conducted in accordance with the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (Serial Designation: C 50 - 24 T) of the American Society for Testing Materials.[1]

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[1] See p. 844.

TENTATIVE SPECIFICATIONS
FOR
QUICKLIME FOR USE IN THE MANUFACTURE OF SULFITE PULP.[1]

Serial Designation: C 46 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

Lime in Manufacture of Sulfite Pulp.

1. Lime is used in the "Milk of Lime" or "Tank System" of sulfite pulp manufacture for making the cooking liquor. The milk of lime is held in solution or suspension in a series of tanks equipped with suitable agitators. The sulfur dioxide is forced or drawn through these tanks successively. In some cases, the tanks are built on top of each other in the form of a tower. The contents of the first tank are drawn off when the liquor has reached a certain strength (3.5 to 6 per cent total SO_2) and the contents of the second and third tanks progress to the first and second tanks respectively. The third tank is again charged with fresh milk of lime. There are other systems of absorption which provide for continuous instead of intermittent operation. The function of the lime is to furnish the base for the formation of the bisulfites of calcium and magnesium.

I. REQUIREMENTS.

Requirements.

2. (*a*) Either calcium or magnesium lime may be used, but owing to the greater solubility and reactivity of magnesium bisulfite, high magnesium lime gives the best results. The ratio of MgO to CaO shall be reasonably constant and the lime shall be moderately free from impurities. The lime shall be of such a physical nature that it will form a rapid settling sludge.

(*b*) The quicklime shall conform to the following requirements as to chemical composition, all percentages to be based on the weight of the sample taken at the point of manufacture.[1]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

	Calcium Lime		Magnesium Lime	
	Maximum	Minimum	Maximum	Minimum
Calcium oxide, per cent	....	92.5	....	55.4
Magnesium oxide, per cent	2.5	....	....	39.6
Oxides of silicon, iron and aluminum, per cent	3.0	....	3.0	....

II. METHODS OF TEST.

Chemical Analysis.

3. The chemical analysis of the lime shall be made in accordance with the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 22 T) of the American Society for Testing Materials.[2]

III. SAMPLING, INSPECTION, REJECTION, ETC.

Sampling, Inspection, Rejection, etc.

The sampling, inspection, rejection, retesting, packing and marking shall be conducted in accordance with the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (Serial Designation: C 50 - 24 T) of the American Society for Testing Materials.[3]

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[1] If it is desired to use the non-volatile basis the figures given above should be changed to the following:

	Calcium Lime		Magnesium Lime	
	Maximum	Minimum	Maximum	Minimum
Calcium oxide, per cent	....	94.3	....	56.5
Magnesium oxide, per cent	2.6	....	....	40.4
Oxides of silicon, iron and aluminum, per cent	3.1	....	3.1	....
Carbon dioxide, per cent	5.0	....	5.0	....

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 715 (1922).

[3] See p. 844.

TENTATIVE SPECIFICATIONS
FOR
QUICKLIME FOR USE IN WATER TREATMENT[1]

Serial Designation: C 53 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Quicklime for Water Treatment.

1. (*a*) In the treatment of water for public supplies, lime is used alone or with iron sulfate or aluminum sulfate to produce a precipitate which assists in the clarification of the water and in the removal of the bacteria by filtration. An excess of lime is sometimes used to remove part of the hardness of the water.

(*b*) Lime and soda ash are used together for softening water.

(*c*) The lime serves as a chemical reagent in water treatment. The only useful constituent of the lime is the calcium oxide capable of reacting with the other chemicals which are in the water or which are added to it. Inert material, besides reducing the value in proportion to its amount, also makes more sludge to be disposed of for a given amount of chemical action and thus reduces the capacity of the equipment in which it is used.

I. REQUIREMENTS

Requirements.

2. (*a*) The lime shall be substantially free of core, ash, and dirt, and shall be capable of disintegrating, in water, into a suspension of finely divided material.

(*b*) The standard composition for quicklime for use in water treatment shall be a content of 90 per cent of available lime. Lime containing less than 80 per cent of available lime shall be rejected as being uneconomical to use. All percentages enumerated herein are based on the sample taken at the point of manufacture.

II. METHODS OF TEST

Chemical Analysis.

3. The chemical analysis for available lime shall be made in accordance with the Tentative Methods of Chemical Analysis of

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 22 T) of the American Society for Testing Materials.[1]

III. SAMPLING, INSPECTION, REJECTION, ETC.

Sampling, Inspection, Rejection, etc.

4. The sampling, inspection, rejection, retesting, packing and marking shall be conducted in accordance with the Tentative Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (Serial Designation: C 50 - 24 T) of the American Society for Testing Materials.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 715 (1922).

[2] See p. 844.

TENTATIVE SPECIFICATIONS
FOR
HYDRATED LIME FOR USE IN WATER TREATMENT[1]

Serial Designation: C 54 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Hydrated Lime for Water Treatment.

1. (*a*) In the treatment of water for public supplies, lime is used alone or with iron sulfate or aluminum sulfate to produce a precipitate which assists in the clarification of the water and in the removal of bacteria by filtration. An excess of lime is sometimes used to remove part of the hardness of the water.

(*b*) Lime and soda ash are used for softening water.

(*c*) Hydrated lime serves as a chemical reagent in water treatment. The only useful constituent of the hydrated lime is the calcium hydroxide capable of reacting with the other chemicals which are in the water or which are added to it. Inert material, besides reducing the value in proportion to its amount, also makes more sludge to be disposed of for a given amount of chemical action and thus reduces the capacity of the equipment in which it is used.

I. REQUIREMENTS

Requirements.

2. The standard composition for hydrated lime for use in water treatment shall be a content of 85 per cent of available calcium hydroxide (equivalent to 64.3 per cent of calcium oxide). Lime containing less than 80 per cent of available calcium hydroxide shall be rejected as uneconomical to use. All percentages enumerated herein are based on the sample taken at the point of manufacture.

II. METHODS OF TEST

Chemical Analysis.

3. The chemical test for available lime shall be made in accordance with the Tentative Methods of Chemical Analysis of Limestone,

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

Quicklime and Hydrated Lime (Serial Designation: C 25 – 22 T) of the American Society for Testing Materials.[1]

III. SAMPLING, INSPECTION, REJECTION, ETC.

Sampling, Inspection, Rejection, etc.

4. The sampling, inspection, rejection, retesting, packing and marking shall be conducted in accordance with the Tentative Methods of Sampling, Inspection, Packing andMarking of Quicklime and Lime Products (Serial Designation C 50 – 24 T) of the American Society for Testing Materials.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 715 (1922).

[2] See p. 844.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE BUILDING BRICK[1]

Serial Designation: C 55 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

I. DEFINITION

Definition.

1. *Concrete Brick.*—For the purpose of these specifications, brick made of portland-cement concrete.

II. STANDARD SIZE

Standard Size.

2. The standard size of concrete building brick shall be $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in.

III. SAMPLING

Sampling.

3. For the purpose of test, bricks shall be selected by an experienced person so as to represent the commercial product. All bricks shall be carefully examined and their condition noted before being subjected to any kind of test. For the purpose of the tests, fifteen bricks will be required; they shall be thoroughly dried to constant weight in a suitable oven at a temperature of from 225 to 250° F. (107 to 121° C.).

IV. PHYSICAL TESTS

Absorption.

4. (*a*) At least five dry bricks shall be weighed and completely submerged in water at a temperature between 60 and 80° F. (15 and 27° C.). The water shall be heated to boiling within one hour, boiled continuously for five hours and then allowed to cool to a temperature between 60 and 80° F. (15 and 27° C.). The bricks shall then be removed, the surface water wiped off with a damp cloth and the bricks quickly weighed.

(*b*) The percentage of absorption shall be calculated on the dry weight from the formula:

$$\text{Percentage of Absorption} = \frac{100\,(B-A)}{A} \times \frac{C}{125}$$

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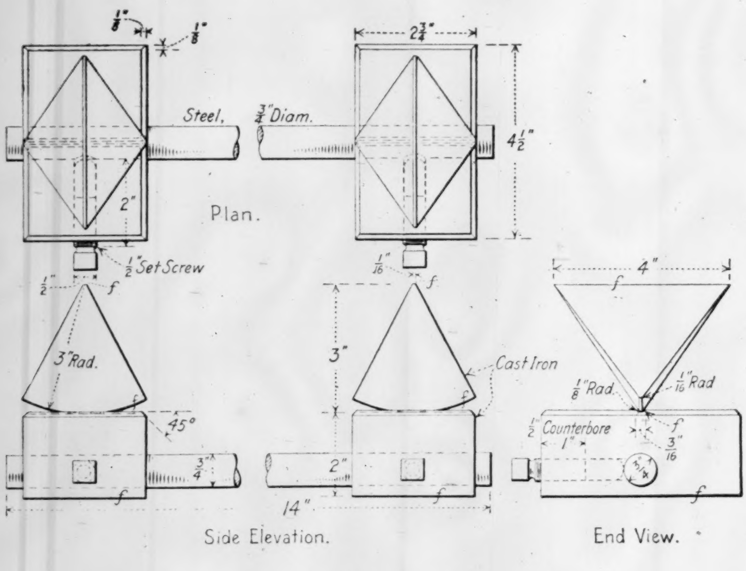
[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. W. E. Emley, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

where A = the weight of the dry brick, B = the weight of the saturated brick, and C = the weight of the dry brick in pounds per cubic foot.

NOTE.—The factor $\frac{C}{125}$ is introducted to correct for variations in the weight per cubic foot of the concrete of which the brick is made.

Compression Tests.

5. (*a*) Compression tests shall be made on at least five whole bricks, previously dried. The specimens shall be tested flat. To secure a uniform bearing in the testing machine, the flat surfaces shall be bedded in a thin coat of calcined gypsum (plaster of Paris), or in a mixture of calcined gypsum and portland cement, spread upon plate glass previously coated with a thin film of oil. Before applying the plaster, the bearing surfaces of the brick shall receive a coating of shellac. The brick shall be pressed firmly upon the surface, making the layer as thin as possible, and shall be permitted to remain undisturbed until set. The depressions of recessed or paneled bricks shall be filled with neat portland-cement mortar, which shall stand at least 24 hours before testing.



1/8"
1/8"
2 3/4"
Steel,
3/4" Diam.
4 1/2"
2"
Plan.
1/2" Set Screw
1/16"
1/2"
f
f
3" Rad.
3"
Cast Iron
4"
f
1/8" Rad.
1/16" Rad
f
45°
1/2" Counterbore
1"
f
3/16"
3/4"
2"
3/4"
f
f
14"
f
Side Elevation.
End View.

FIG. 1.

(*b*) The machine used for the compression tests shall be equipped with a spherical bearing block kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load. The spherical bearing block shall be used on top of the specimen. During the test, the beam of the testing machine shall be kept constantly in a floating position.

(*c*) The breaking load shall be divided by the area in compression and the results reported in pounds per square inch.

Transverse Tests.

6. (*a*) At least five bricks, previously dried, shall be tested, laid flat-wise on knife edges with a span of 7 in. and with the load applied at midspan. Steel bearing plates, $\frac{1}{4}$ in. in thickness by $1\frac{1}{2}$ in. in width, shall be placed between the knife edges and the brick. The upper edges of the knife edges shall be straight and have full contact with the $\frac{1}{4}$-in. bearing plates. They shall have a length at least equal to the width of the brick to be tested. Their bases shall be so curved or rounded as to permit free movement of the upper edges both longitudinally and transversely. The use of knife edges of the type shown in Fig. 1 is recommended, although other types may be used which will provide free movement at the ends and at the same time insure full and even bearing at all times during the test.

(*b*) The modulus of rupture shall be calculated in pounds per square inch from the formula:

$$R=\frac{3\ Wl}{2\ bd^2}$$

in which l = the distance between the supports in inches, b = the breadth and d = the depth of the brick in inches, and W = the load in pounds at which the brick failed.

Records of Test Results.

7. In recording the results of the tests the type of brick shall be defined, whether dry pressed, or wet mixed. It is recommended that the data obtained be recorded as indicated on the accompanying "Laboratory Record."

V. TEST REQUIREMENTS

Test Requirements.

8. (*a*) When sampled at the plant, the age of concrete bricks when tested shall be not less than 28 days nor more than 60 days. Tests may be made on the brick delivered on the job.

(*b*) The bricks shall meet the following physical requirements:

Kind of Brick	Absorption Limits, per cent		Compressive Strength (flat), lb. per sq. in.		Modulus of Rupture, lb. per sq. in.	
	Mean of 5 Tests, Maximum	Individual Maximum	Mean of 5 Tests, Minimum	Individual Minimum	Mean of 5 Tests, Minimum	Individual Minimum
Face brick	10	12	1500	1000	300	250
Common brick	12	15	1500	1000	300	250

LABORATORY RECORD

THE ENGINEERING LABORATORY OF ....

Brick received from ....

Address ....

Sampled by .... Date ....

Type .... Class (A.S.T.M.) ....

Appearance of bricks ....

ABSORPTION TEST

Sample No.	Weight			Absorption, per cent $\frac{100\,B-A}{A}\times\frac{C}{125}$	Remarks
	Dry (A)	Saturated (B)	Difference (B-A)		
1					
2					
3					
4					
5					
Sum					
Average					

COMPRESSION TEST
(WHOLE BRICKS TESTED FLAT.)

Sample No.	Dimensions of Brick			Load		Compressive Strength, $\left(\frac{L}{a}\right)$ lb. per sq. in.	**Remarks**
	Width (b), in.	Length (l), in.	Area (a) $a=bl$	At First Crack, lb.	At Failure (L), lb.		
1							
2							
3							
4							
5							
Sum							
Average							

LABORATORY RECORD.—*Continued.*

TRANSVERSE TEST

Sample No.	Dimensions			Load (W), lb.	Modulus of Rupture, $R=\frac{3Wl}{2bd^2}$	Remarks
	Width (b), in.	Depth (d), in.	Span (l), in.			
1						
2						
3						
4						
5						
Sum		....	....	....		
Average		....	....	....		

SUMMARY

Average Absorption, per cent	Average Compressive Strength, lb. per sq. in.	Average Modulus of Rupture

Observers:

....

.... *In charge of tests.*

TENTATIVE SPECIFICATIONS AND TESTS FOR HOLLOW BURNED-CLAY LOAD-BEARING WALL TILE[1]

Serial Designation: C 34 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1921; REVISED, 1924

SPECIFICATIONS

Application.

1. These specifications apply to hollow load-bearing wall tile made from surface clay, shale, fire clay or admixtures thereof.

I. CLASSIFICATION

Classification.

2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium, and Soft on the basis of the following requirements:[2]

Class	Absorption, per cent		Compressive Strength, Based on Gross Area, lb. per sq. in.[a]			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	1800 or more	1400	1000 or more	700
Medium	12 to 16	19	1800 to 1400	1000	1000 to 700	500
Soft	16 to 25	28	1400 to 1200	700	700 to 500	350

[a] Gross area shall be taken as the total area enclosed by the outside dimensions of the unit taken in a direction perpendicular to that in which the load is carried.

(*b*) Where end-construction tile are used on the side they shall meet the requirements of that construction, and *vice versa*.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. F. J. Huse, Secretary of Committee C-10 on Hollow Building Tile, The Hollow Building Tile Association, 1409 Conway Building, Chicago, Ill.

[2] As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

II. WEIGHTS

Weights.

3. (*a*) The tile shall have the following dry weights determined as hereinafter specified:

SIZE OF UNIT, in.	NUMBER OF CELLS	STANDARD WEIGHT, LB.
3¾ by 12 by 12	3	20
6 by 12 by 12	6	30
8 by 12 by 12	6	36
10 by 12 by 12	6	42
12 by 12 by 12	6	48
3¾ by 5 by 12	1	9
8 by 5 by 12	2	16
8 by 5 by 12 ("L" Shaped)	..	16
8 by 6¼ by 12 ("T" Shaped)	4	16
8 by 7¾ by 12 (Square)	6	24
8 by 10¼ by 12 ("H" Shaped)	7	32

(*b*) A tolerance of 5 per cent will be allowed on the above standard weights.

III. DIMENSIONS

Dimensions.

4. No dimension shall vary more than 3 per cent from the standard dimensions for any form of tile.

IV. WEATHERING RESISTANCE

Weathering Resistance.

5. All tile used in exterior work subjected to weathering conditions shall be able to withstand 100 alternate freezings and thawings. Tile classed as hard or medium by these specifications may be considered as meeting the weathering requirement, provided they are burned to the normal maturity for the given clay. Tile classed as soft shall be accepted as meeting the weathering requirement only on the basis of freezing tests.

V. FIRE RESISTANCE

Fire Resistance.

6. The tile shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C 19) of the American Society for Testing Materials[1] as they apply to load-bearing walls and partitions, and to be acceptable shall develop the safe resistance period specified in the contract and in all cases shall give a resistance of not less than that equivalent to the requirements for the one-hour classification where the fire resistance of the construction is limited by the properties of the tile. The manufacturer shall supply such available information on the fire test performance

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[1] 1924 Book of A.S.T.M. Standards.

of the given or closely similar product as will aid the purchaser in deciding whether his requirements are met. Further tests in accordance with the above-named standards may be conducted by the purchaser.

VI. WORKMANSHIP AND FINISH

Workmanship. 7. All tile shall be well burned, reasonably free from laminations and from such cracks, blisters, surface roughness, and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring. 8. The exterior surface of all tile intended for plaster or stucco shall be scored in such a manner as to give good anchorage.

VII. MARKING

Marking. 9. All tile shall bear the word "Load-Bearing" and initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

VIII. INSPECTION AND REJECTION

Inspection. 10. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified in the contract. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed.

Rejection. 11. (*a*) Individual tile shall be rejected for failure to meet the weight, size, workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected from the retained lot and tested at his expense. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

Acceptance. (*b*) By agreement, acceptance may be based on dry weight of the units, percentage of absorption, fire resistance and the workmanship and finish, except that where loads approximating working-load values will be imposed on the tile construction, the tests for compressive strength shall also be made and the tile shall meet the compressive strength requirements for the given class of tile.

Expense of Tests. 12. Except as specified in Section 11 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

TESTS

IX. SAMPLING

13. Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases. **Selection of Samples for Test.**

14. For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. Samples for the freezing tests shall be taken from tile that have not been subjected to strength or fire tests. **Number of Samples.**

15. Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified. If the fire or freezing tests are to be made it shall be so specified at the time of placing the order, samples for fire tests being selected at the factory at least 45 days in advance of the time of filling the order and 90 days in advance for freezing tests. **Time and Place of Selecting Samples.**

16. All tile selected for test shall be plainly and permanently marked for reference by the testing operator. **Marking Samples.**

X. WEIGHT DETERMINATIONS

17. The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100° C. (212° F.) and be weighed separately. The scale shall be sensitive to within 0.5 per cent of the weight of the smallest unit. **Weight Determinations.**

XI. STRENGTH TESTS

18. Five full-size dry tile shall be used. **Samples.**

19. The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute. **Speed of Testing Machine.**

20. A spherical bearing block of proper design shall be placed on top of the test sample. **Bearing Block.**

21. (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with one coat of shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plain surface which has been coated with oil, and allowed to harden suffi- **Capping.**

ciently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $\frac{1}{8}$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. Any other method of capping which produces equally satisfactory results may be used.

Time of Testing. 22. When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped.

Position of Tile. 23. All tile shall be tested in the position in which they are designed to be used.

XII. ABSORPTION TESTS

Selection of Test Samples. 24. The samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used, two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. ($\frac{1}{2}$ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

Marking Test Samples. 25. Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5 per cent of the total superficial area of the piece shall be used.

Drying the Test Samples. 26. Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100° C. (212° F.).

Accuracy of Weighings. 27. The balance used shall be sensitive to within 0.5 per cent of the weight of the smallest unit.

Saturation of Samples. 28. After obtaining the dry weight of the samples they shall be immersed in soft, distilled or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature.

29. After saturation, the sample shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately. **Obtaining Saturated Weights.**

30. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile. **Calculating and Reporting Results.**

XIII. FREEZING TESTS

31. Where the freezing test is to be made, five separate representative tile shall be selected. **Sampling.**

32. If not possible to use the whole tile, a piece consisting of a cell not less than 4 in. long shall be sawed from the tile. These pieces shall be saturated by immersion in cold water for at least 72 hours prior to starting the freezing. **Preparation of Samples.**

33. Any practical method of obtaining alternate freezings and thawings may be used, the freezings to be always made with fully saturated samples and the time and temperature to be such as to insure full freezing and thawing throughout the specimen. The initial weighing and all weighings for loss shall be made on dry specimens. **Method.**

34. Failure under the freezing and thawing treatment shall be considered to be reached when: **Interpretation of Results.**

(*a*) The samples show superficial disintegration or spalling with loss of weight of more than 5 per cent of the initial weight; or

(*b*) The samples are badly cracked; or

(*c*) The samples show evident loss of structural strength.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
HOLLOW BURNED-CLAY FIREPROOFING, PARTITION AND FURRING TILE[1]

Serial Designation: C 56 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924.

SPECIFICATIONS

Application. 1. These specifications apply to hollow fireproofing, partition and furring tile made from surface clay, shale, fire clay or admixtures thereof.

I. CLASSIFICATION

Classification. 2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium, and Soft on the basis of the following requirements:[2]

Class	Absorption, per cent		Compressive Strength Based on Net Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	3000 or more	2500	2000 or more	1500
Medium	12 to 20	25	3000 to 2000	1500	2000 to 1250	1000
Soft	20 to 28	35	2000 to 1000	750	1250 to 750	500

(*b*) Where end-construction tiles are used on the side they shall meet the requirements of that construction, and *vice versa*.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. F. J. Huse, Secretary of Committee C-10 on Hollow Building Tile, The Hollow Building Tile Association, 1409 Conway Building, Chicago, Ill.

[2] As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

II. WEIGHTS

Weights.

3. (*a*) The tile shall have the following dry weights determined as hereinafter specified:

STANDARD PARTITION TILE

DIMENSIONS, IN.	NUMBER OF CELLS	STANDARD WEIGHT, LB.
3 by 12 by 12	3	15
4 by 12 by 12	3	16
6 by 12 by 12	3	22
8 by 12 by 12	4	30
10 by 12 by 12	4	36
12 by 12 by 12	4	40

(*b*) A tolerance of 5 per cent will be allowed on the above standard weights.

III. DIMENSIONS

Dimensions.

4. No dimension shall vary more than 3 per cent from the standard dimensions for any form of tile.

IV. FIRE RESISTANCE

Fire Resistance.

5. In cases where the fire resistance is an essential property, the tile shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C 19) of the American Society for Testing Materials,[1] as they apply for the construction in which the tile are used. The purchaser shall specify the degree of fire resistance required (fire-resistance period), and the manufacturer shall supply such available information on fire test performance of the given or closely similar product as will aid the purchaser in deciding whether the requirements are met. Further tests in accordance with the above-named standards may be conducted by the purchaser.

V. WORKMANSHIP AND FINISH

Workmanship.

6. All tile shall be well burned, reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would evidently interfere with the proper setting of the tile or impair the permanence of the construction.

Scoring.

7. The exterior surface of all tile intended for plaster shall be scored in such a manner as to give good anchorage.

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[1] 1924 Book of A.S.T.M. Standards.

VI. MARKING

Marking. 8. All tile shall bear the initials, name or trademark of the manufacturer. Hollow tile intended for use in partitions shall also be marked "PARTITION." These marks shall be indented on the exterior of the tile and shall be plainly legible.

VII. INSPECTION AND REJECTION

Inspection. 9. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified in the contract. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed.

Rejection. 10. (*a*) Individual tile shall be rejected for failure to meet the weight, size, workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected from the retained lot and tested at his expense. In case the second set of samples fails to meet the test requirements, the entire lot shall be rejected.

Acceptance. (*b*) By agreement, acceptance may be based on dry weight of the units, percentage of absorption, fire resistance and the workmanship and finish.

Expense of Tests. 11. Except as specified in Section 10, and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

TESTS

VIII. SAMPLING

Selection of Samples for Test. 12. Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases.

Number of Samples. 13. For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required.

Time and Place of Selecting Samples. 14. Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified in the contract. If the fire tests are to be made, it shall be so specified at the time of placing the order, samples being selected at the factory at least 45 days in advance of the time of filling the order.

15. All tile selected for test shall be plainly and permanenlty marked for reference by the testing operator. **Marking Samples.**

IX. WEIGHT DETERMINATIONS

16. The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100° C. (212° F.) and be weighed separately. The scale shall be sensitive to within 0.5 per cent of the weight of the smallest unit. **Weight Determinations.**

X. STRENGTH TESTS

17. Five full-size dry tile shall be used. **Samples.**

18. The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute. **Speed of Testing Machine.**

19. A spherical bearing block of proper design shall be placed on top of the test sample. **Bearing Block.**

20. (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with one coat of shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plain surface which has been coated with oil, and allowed to harden sufficiently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure. **Capping.**

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $\frac{1}{8}$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. Any other method of capping which produces equally satisfactory results may be used.

21. When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped. **Time of Testing.**

22. All tile shall be tested in the position in which they are designed to be used. **Position of Tile.**

XI. ABSORPTION TESTS

Selection of Test Samples. 23. The samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. ($\frac{1}{2}$ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

Marking Test Samples. 24. Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5 per cent of the total superficial area of the piece shall be used.

Drying the Test Samples. 25. Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100° C. (212° F.).

Accuracy of Weighings. 26. The balance used shall be sensitive to within 0.5 per cent of the weight of the smallest unit.

Saturation of Samples. 27. After obtaining the dry weight of the samples they shall be immersed in soft, distilled or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature.

Obtaining Saturated Weights. 28. After saturation, the sample shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately.

Calculating and Reporting Results. 29. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
HOLLOW BURNED-CLAY FLOOR TILE[1]

Serial Designation: C 57 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

SPECIFICATIONS

Application. 1. These specifications apply to hollow floor tile made from surface clay, shale, fire clay or admixtures thereof.

I. CLASSIFICATION

Classification. 2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium, and Soft on the basis of the following requirements:[2]

Class	Absorption, per cent		Compressive Strength Based on Net Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	4000 or more	3200	2500 or more	2000
Medium	12 to 16	19	4000 to 3000	2400	2500 to 1800	1400
Soft	16 to 25	28	3000 to 2200	1700	1800 to 1300	1000

(*b*) Where end-construction tile are used on the side they shall meet the requirements of that construction, and *vice versa.*

II. WEIGHTS

Weights. 3. (*a*) The tile shall have the following dry weights determined as hereinafter specified:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. F. J. Huse, Secretary of Committee C-10 on Hollow Building Tile, The Hollow Building Tile Association, 1409 Conway Building, Chicago, Ill.

As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

FLAT ARCH

DEPTH OF ARCH, IN.	AVERAGE WEIGHT PER SQUARE FOOT, LB.
6	26
7	29
8	32
9	35
10	38
12	42
15	50

SEGMENTAL ARCH

DEPTH OF ARCH, IN.	AVERAGE WEIGHT PER SQUARE FOOT, LB.
6	30
8	36
10	40

TILE FOR USE IN COMBINATION HOLLOW TILE AND CONCRETE CONSTRUCTION

SIZE OF UNIT, IN.	NUMBER OF CELLS	STANDARD WEIGHT, LB.
4 by 12 by 12	3	16
6 by 12 by 12	3	22
8 by 12 by 12	4	30
10 by 12 by 12	4	36
12 by 12 by 12	4	40

(*b*) A tolerance of 5 per cent will be allowed on the above standard weights.

III. DIMENSIONS

Dimensions. 4. No dimension shall vary more than 3 per cent from the standard dimensions for any form of tile.

IV. FIRE RESISTANCE

Fire Resistance. 5. The tile shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C 19) of the American Society for Testing Materials,[1] as they apply to hollow floor tile, and to be acceptable shall develop the safe resistance period specified in the contract. The manufacturer shall supply such available information on the fire test performance of the given or closely similar product as will aid the purchaser in deciding whether his requirements are met. Further tests in accordance with the above named standards may be conducted by the purchaser.

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[1] 1924 Book of A.S.T.M. Standards.

V. WORKMANSHIP AND FINISH

Workmanship. 6. All tile shall be well burned, reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring. 7. The exterior surface of all tile intended for plaster shall be scored in such a manner as to give good anchorage.

VI. MARKING

Marking. 8. All tile shall bear the initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

VII. INSPECTION AND REJECTION

Inspection. 9. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed.

Rejection. 10. (*a*) Individual tile shall be rejected for failure to meet the weight, size, workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected from the retained lot and tested at his expense. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

Acceptance. (*b*) By agreement, acceptance may be based on dry weight of the units, percentage absorption, fire resistance and the workmanship and finish.

Expense of Tests. 11. Except as specified in Section 10 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

TESTS

VIII. SAMPLING

Selection of Samples for Test. 12. Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases.

Number of Samples. 13. For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. Where tile of several designs are used, enough samples shall be weighed to determine the true average weight in pounds per square foot for the construction. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. Samples for the freezing tests shall be taken from tile that have not been subjected to strength or fire tests.

Time and Place of Selecting Samples. 14 Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified in the contract. If the fire tests are to be made, it shall be so specified at the time of placing the order, samples being selected at the factory at least 45 days in advance of the time of filling the order.

Marking Samples. 15. All tile selected for test shall be plainly and permanently marked for reference by the testing operator.

IX. WEIGHT DETERMINATIONS

Weight Determinations. 16. The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100° C. (212° F.) and be weighed separately. The scale shall be sensitive to within 0.5 per cent of the weight of the smallest unit.

X. STRENGTH TESTS

Samples. 17. Five full-size dry tile shall be used.

Speed of Testing Machine. 18. The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute.

Bearing Block. 19. A spherical bearing block of proper design shall be placed on top of the test sample.

Capping. 20. (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with one coat of shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plain surface which has been coated with oil, and allowed to harden sufficiently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $\frac{1}{8}$ in.

Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. Any other method of capping which produces equally satisfactory results may be used.

Time of Testing.

21. When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped.

Position of Tile.

22. In the tests, the tile shall be loaded in the direction in which they receive the principal stress in the structure.

XI. ABSORPTION TESTS

Selection of Test Samples.

23. The samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. ($\frac{1}{2}$ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

Marking Test Samples.

24. Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5 per cent of the total superficial area of the piece shall be used.

Drying the Test Samples.

25. Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100° C. (212° F.).

Accuracy of Weighings.

26. The balance used shall be sensitive to within 0.5 per cent of the weight of the smallest unit.

Saturation of Samples.

27. After obtaining the dry weight of the samples they shall be immersed in soft, distilled or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature.

Obtaining Saturated Weights.

28. After saturation, the sample shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately.

Calculating and Reporting Results.

29. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM.[1]

Serial Designation: C 22 – 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1919; REVISED, 1920, 1921, 1922, 1923, 1924.

I. MATERIALS AND STANDARDS.

Testing.

1. The chemical and physical properties of gypsum shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26) of the American Society for Testing Materials.[2]

Definition.

2. (*a*) Pure gypsum is calcium sulfate combined in crystallin form with two molecules of water.

(*b*) Its chemical formula is $CaSO_4 \cdot 2H_2O$.

(*c*) No material may be considered gypsum within the meaning of these specifications which contains less than 64.5 per cent by weight of $CaSO_4 \cdot 2H_2O$.

Forms and Sizes.

3. Gypsum may be in any of the following forms and sizes:

(*a*) *Run-of-Mine Gypsum.*—The form in which it comes from the mine or quarry.

(*b*) *Crushed Gypsum.*—Run-of-mine gypsum further reduced so that all of it will pass a 3-in. (76-mm.) ring, and not more than 25 per cent shall pass a No. 100 sieve.

(*c*) *Sized Gypsum.*—Shall all pass a 1½-in. (38-mm.) ring, and not more than 10 per cent shall pass a ¼-in. sieve.

(*d*) *Ground Gypsum.*—Gypsum further reduced for specific uses. Ground gypsum may be in any of the following standard forms:

No. 1.—This material shall all pass a No. 14 sieve, and not less than 85 per cent of it shall pass a No. 100 sieve.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 844 Rush St., Chicago, Ill.

[2] 1924 Book of A.S.T.M. Standards.

No. 2.—This material shall all pass a No. 14 sieve, and not less than 60 nor more than 85 per cent of it shall pass a No. 100 sieve.

No. 3.—This material shall all pass a No. 8 sieve, and not less than 40 nor more than 60 per cent of it shall pass a No. 100 sieve.

No. 4.—This material shall all pass a No. 100 sieve.

NOTE.—All Sieve numbers refer to United States Standard Sieve Series.[1]

Chemical Properties.

4. The chemical composition, within the limits prescribed by Section 2, shall be a matter of contract.

II. SAMPLING.

Sampling from Bulk.

5. When gypsum is shipped in bulk, samples of about 5 lb. (2.25 kg.) each shall be taken at regular intervals during the complete loading or unloading of the carrier, in such a way as to accumulate at least 200 lb. (90 kg.) of material, and to represent correctly the percentages of both the coarse particles and the fines in the shipment. This shall be broken so that it will all pass a 1-in. (25-mm.) ring, thoroughly mixed, and reduced by quartering to provide not less than a 1-lb. (0.5-kg.) sample for the laboratory.

Sampling from Packages.

6. When gypsum is shipped in packages, at least 3 per cent of the packages shall be sampled. Samples shall be taken from both the surface and the center of the packages. These samples shall then be broken, mixed, and quartered as directed above.

Laboratory Samples.

7. All laboratory samples shall be placed immediately in an air-tight container and shipped to the laboratory for test.

III. PACKING AND MARKING.

Packing and Marking.

8. (*a*) Gypsum may be shipped either in packages or in bulk.

(*b*) When shipped in packages for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of manufacturer;
Form and size of material;
Chemical analysis of the material, giving the minimum percentages of CaO and SO_3;
Net weight of package.

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[1] For detailed specifications for these sieves, see U. S. Bureau of Standards *Letter Circular No. 74.*

(*c*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

IV. INSPECTION AND REJECTION.

Inspection. 9. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 10. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications, and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing. 11. Claims for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM PLASTERING SAND.[1]

Serial Designation: C 35 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1924.

Definition.

1. Sand used for plastering purposes, in which a gypsum plaster is employed, shall be the fine granular material naturally or artificially produced by the disintegration of rock containing not less than 80 per cent by weight of fine silica, feldspar, dolomite or calcite.

Composition.

2. (*a*) It shall be free from salt and from alkaline, organic or other deleterious substances.

(*b*) It shall be graded from fine to coarse, and when dry, not more than 10 per cent by weight shall be retained on a No. 8 sieve; not less than 80 per cent by weight shall be retained on a No. 50 sieve; and not more than 6 per cent by weight shall pass a No. 100 sieve. These sieves shall meet the specifications given in the United States Standard Sieve Series.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 844 Rush St., Chicago, Ill.

[2] For detailed specifications for these sieves, see U. S. Bureau of Standards *Letter Circular No. 74.*

TENTATIVE SPECIFICATIONS
FOR
GYPSUM WALL BOARD.[1]

Serial Designation: C 36 – 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1922, 1924.

Definition. 1. Gypsum wall boards are incombustible boards which, without the addition of plaster, furnish to interior walls, ceilings or partitions a surface which may receive decoration.

Composition. 2. Gypsum wall boards consist of sheets or slabs composed of one layer of gypsum, with or without fiber, reinforced on the surfaces with a covering made from fibrous material.

Thickness. 3. Gypsum boards shall be $\frac{3}{8}$ in. (9.5 mm.) thick with permissible local variations of $\pm\frac{1}{32}$ in. (0.8 mm.).

NOTE.—Gypsum wall boards are manufactured in thicknesses from $\frac{1}{4}$ in. (6.3 mm.) to $\frac{1}{2}$ in. (12.7 mm.) with permissible local variations of $\pm\frac{1}{32}$ in. (0.8 mm.) from the nominal thickness

Dimensions. 4. (*a*) Gypsum wall boards that are to be laid with the joints butted shall have widths of 32 in. (810 mm.), 36 in. (910 mm.), or 48 in. (1220 mm.), except that a variation of $\frac{3}{32}$ in. (2 mm.) under the specified widths is permissible.

(*b*) Gypsum wall boards that are to be laid with the joints filled shall have widths $\frac{1}{4}$ in. (6.3 mm.) less than those specified in Paragraph (*a*) except that the same variation is permissible.

(*c*) The lengths shall be from 4 ft. (1.22 meter) to 12 ft. (3.66 meter) inclusive, except that a tolerance of $\frac{3}{8}$ in. (9.5 mm.) from the length of individual boards is permissible. Special boards may be cut to any desired length within the limits prescribed.

Weight 5. The weight of gypsum wall board shall be not less than 1500 lb. (680 kg.) nor more than 2000 lb. (907 kg.) per 1000 sq. ft.

Strength. 6. (*a*) Strength test specimens shall be 12 in. (300 mm.) wide and approximately 18 in. (460 mm.) long, and when tested shall be supported on parallel knife-edge bearings spaced 16 in. (410 mm.) apart, and shall be loaded through a similar bearing midway between the supports.

(*b*) When tested as described, specimens taken from the gypsum wall boards shall carry a load of not less than 60 lb. (27.22 kg.) when the knife edges are across the fiber of the surfacing, and not less than

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 844 Rush St., Chicago, Ill.

32 lb. (14.51 kg.) when the knife edges are parallel to the fiber of the surfacing.

(*c*) With loads equal to or less than those specified in Paragraph (*b*) there shall be no breaking of the bond between the surfacing and the core.

Finish.

7. That surface of the gypsum wall board designed to be exposed on erection shall be true and free from imperfections that would render the wall boards unfit for use with or without decorations. The edges and ends shall be straight and solid. Boards that are to be butted shall have corners square and opposite edges parallel to each other. With boards that are to have the joints filled, a negative variation of $\frac{1}{8}$ in. (3 mm.) from parallelism of opposite edges is permissible.

Sampling.

8. At least one per cent of the number of gypsum wall boards in a shipment, but not less than ten boards, shall be so selected as to be representative of the shipment. Twenty-five per cent of such selected boards, but not less than ten individual boards, shall constitute a sample for test purposes. When a shipment consists of more than one car or carrier load, a sample shall be selected from each car or carrier.

Packing and Marking.

9. Shipments of gypsum wall board shall conform to the following:

(*a*) They shall be shipped so as to be kept dry and free from moisture.

(*b*) When shipped for resale the following information shall be shown upon each board:

Name of manufacturer;
Brand;
Nominal thickness.

Inspection.

10. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection.

11. Any rejection shall be based upon failure to conform to the requirements of these specifications and shall be reported within ten working days from the receipt of the shipment by the consignee. The notice of rejection shall contain a specific statement of the respects in which the boards have failed to meet the requirements of these specifications.

Rehearing.

12. Claims for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM PARTITION TILE OR BLOCK[1]

Serial Designation: C 52 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1923; REVISED, 1924

Definition. 1. Gypsum partition tile or block is a building unit used for non-bearing construction in the interior of buildings.

NOTE.—The words "tile" and "block" are synonymous and are used so as to be in accord with certain freight association nomenclature.

Uses. 2. (*a*) It is also used as a protection for columns, elevator shafts, etc., against fire.

(*b*) Gypsum cored tile, 3 or 4 in. in thickness, may be split and used for furring purposes.

Composition. 3. Gypsum tile consists of gypsum with or without an aggregate.

Form and Size. 4. Gypsum partition tile shall be rectangular in shape with straight and square edges and true surfaces. They may also be of special shape provided the requirements as otherwise mentioned herein, are met. They may be solid or cored and shall preferably be 12 by 30 in. in face dimensions.

Core Spaces. 5. (*a*) The core spaces shall be symmetrically spaced and so located as to result in the most economical and even distribution of material.

(*b*) *Circular Core Spaces.*—The cross-sectional dimensions of gypsum partition tile with circular core spaces shall conform to the following:

THICKNESS OF TILE OR BLOCK, IN.	SIDE SHELL THICKNESS, IN.		EDGE SHELL THICKNESS, IN.
	NOMINAL	MINIMUM	MINIMUM
2	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$
$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$
3	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$
4	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{4}$
5	1	$\frac{7}{8}$	1
6	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$
8	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 844 Rush St., Chicago, Ill.

The sum of the widths of the two side shells plus the width of the center vertical web shall be not less than 2 in. in the case of 6-in. tile or block, and not less than $2\frac{1}{2}$ in. in the case of 8-in. tile or block.

(*c*) *Elliptical or Rectangular Core Spaces.*—The cross-sectional dimensions of gypsum partition tile or block with elliptical or rectangular core spaces shall be such as to provide for a shell thickness, at the thinnest point, of not less than 15 per cent of the maximum height of the adjacent core space, and in no case shall the shell thickness be less than the following:

THICKNESS OF TILE OR BLOCK, IN.	MINIMUM SIDE OR EDGE SHELL THICKNESS, IN.
2	$\frac{9}{16}$
$2\frac{1}{2}$	$\frac{9}{16}$
3	$\frac{11}{16}$
4	$\frac{13}{16}$
5	$1\frac{1}{8}$
6	$\frac{11}{16}$
8	$\frac{13}{16}$

The sum of the widths of the two side shells plus the width of the center vertical web shall not be less than $2\frac{3}{4}$ in. in the case of 6-in. tile or block, and not less than $3\frac{1}{4}$ in. in the case of 8-in. tile or block.

Dimensions.

6. (*a*) Gypsum tile may be of any convenient length and height, but in general it shall not exceed 30 in. in length and 12 in. in height. The thickness shall be uniform throughout and within the limits specified in Paragraph (*b*).

(*b*) *Thickness.*—Gypsum tile or block shall conform to the specified thicknesses with the following permissible variations:

NOMINAL SIZE OF TILE OR BLOCK, IN.	MINIMUM THICKNESS, IN.	MAXIMUM THICKNESS, IN.
$1\frac{1}{2}$ (Furring)	$1\frac{3}{8}$	$1\frac{5}{8}$
2 (Furring)	$1\frac{7}{8}$	$2\frac{1}{8}$
2	2	$2\frac{1}{4}$
$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{3}{4}$
3	$2\frac{7}{8}$	$3\frac{1}{4}$
4	$3\frac{7}{8}$	$4\frac{1}{4}$
5	$4\frac{7}{8}$	$5\frac{1}{4}$
6	$5\frac{3}{4}$	$6\frac{1}{4}$
8	$7\frac{3}{4}$	$8\frac{1}{4}$

(*c*) *Dimension Determinations.*—Over-all dimensions shall be measured from opposite face to opposite face of the tile or block, the greatest measurement observed being taken as the dimension.

Sectional dimensions of cored tile shall be taken 1 in. in from the ends of the tile or block, the least measurement observed being taken as the dimension.

Shell dimensions shall be measured from the surface of the core space to the normal surface of the tile or block inside the scoring.

(*d*) *Dimension Tolerances.*—A variation of $\frac{1}{4}$ in. in the nominal width and $\frac{3}{8}$ in. in the nominal length of the tile or block is permissible.

(*e*) *Scoring.*—The scoring upon gypsum tile or block shall be of such a nature as not to materially reduce the shell thickness.

Strength. 7. (*a*) The ultimate compressive strength of gypsum tile or block, dried to constant weight at a temperature not exceeding 110° F. (43° C.), and uniformly loaded upon the bearing area (one edge), shall be not less than 75 lb. per sq. in. for the average of five specimens tested.

(*b*) When completely saturated, the ultimate compressive strength shall be not less than $33\frac{1}{3}$ per cent of the ultimate strength required for such tile or block when dried to constant weight.

(*c*) The rate of absorption of gypsum tile or block shall be not less than 10 cc. nor more than 30 cc. for the first minute, nor less than 7 cc. for each of the next five subsequent minutes.

Fire Resistance. 8. In locations where fire resistance is an essential property, gypsum tile or block shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C 19) of the American Society for Testing Materials,[1] as they apply for the construction in which the tile are used.

Sampling. 9. At least 1 per cent of the number of gypsum tile or block in a shipment, but in no case less than ten tile, shall be so selected as to be representative of the shipment. Twenty-five per cent of such selected tile, but in no case less than ten individual tile, shall constitute a sample for test purposes. In case a shipment consists of more than one car or carrier load, a sample shall be selected from each car or carrier. Samples for test shall be selected at the factory or at the point of delivery, as specified in the sales contract.

Marking. 10. When gypsum tile or block are shipped for resale, the manufacturer's "Brand" name shall be shown upon each tile.

Inspection. 11. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

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[1] 1924 Book of A.S.T.M. Standards.

12. Any rejection shall be based upon failure to conform to the requirements of these specifications, and shall be reported within ten working days from the receipt of the shipment by the consignee. The notice of rejection shall contain a specific statement of the respects in which the tile or block have failed to meet the requirements of these specifications. **Rejection.**

13. Claims for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection. **Rehearing.**

TENTATIVE METHODS OF SAMPLING, INSPECTION, PACKING AND MARKING OF QUICKLIME AND LIME PRODUCTS[1]

Serial Designation: C 50 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1922; Revised, 1923, 1924

I. METHODS OF SAMPLING

A. General

General. 1. (*a*) Samples of quicklime and lime products shall be taken at one of the following places, as may be agreed upon by the contracting parties:

> At point of manufacture, or destination: From conveyors delivering to bins or piles, from filled bins by means of sampling tubes, from filled bins at the point of discharge, from piles by means of sampling tubes or shovels, or from loaded cars.

(*b*) All samples shall be taken in triplicate and immediately sealed in air-tight moisture-proof containers.

(*c*) One sample shall be immediately delivered to the consignee; one sample shall be delivered to the consignor if requested within 10 days from the date of sampling; the third sample shall be retained with seal unbroken until such time as the material has been accepted or a referee test called for.

(*d*) Samples shall be of an equal weight of not less than 5 lb. each when the quantity sampled equals 30 tons or more. For smaller quantities, the weights of the samples may be reduced proportionately, provided that no sample shall weigh less than 2 lb., except by special agreement of the contracting parties.

(*e*) If the samples are taken at any place other than the place of manufacture of the material being sampled, such samples shall be taken within 24 hours of the receipt of the material.

(*f*) Sampling shall be conducted as expeditiously as possible in order to avoid undue exposure of the material to the air.

(*g*) Samples shall not be taken from the broken packages.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

B. Lump or Granular Material

Lump or Granular Material in Bulk.

2. (*a*) *In Bulk* (Piles or cars).—Material shall be selected so that it will represent an average of all parts of the pile or car and shall not contain a disproportionate share of the top or bottom layers. This material shall comprise at least 10 shovelfuls taken from different parts of the pile or car. The total material so taken shall weigh not less than 100 lb. for a 30-ton unit, with a proportionate quantity of material for multiples of this unit, provided that at no time shall the total amount of material so taken weigh less than 50 lb. It shall be broken, if necessary, to pass a 1-in. ring, thoroughly mixed, and quartered, and the triplicate samples for testing shall be taken from the material so drawn and prepared.

(*b*) *In Bulk* (At conveyors to or from bins, piles or cars).—Material shall be taken at regular intervals during the entire time of movement of the mass being sampled. The quantity to be taken at each interval and the number of such intervals shall be so proportioned that the final quantity of material taken shall conform to the requirements of Paragraph (*a*).

Lump or Granular Material in Packages.

3. *In Packages.*—At least 2 per cent of the packages shall be sampled, the packages to be taken from various parts of the material being sampled, and at no time shall less than 5 packages be sampled. The contents of each of the packages so taken shall be put in a pile, broken, if necessary, to pass a 1-in. ring, thoroughly mixed, and quartered, and the triplicate samples for testing shall be taken from the material so drawn and prepared.

C. Powdered Material

Powdered Material in Bulk.

4. (*a*) *In Bulk* (Bins, piles or cars).—A sampling tube shall be used which takes a core not less than 1 in. in diameter, and which is of sufficient length to permit the taking of a core from the top to the bottom of the mass being sampled. Cores shall be taken from at least 10 separate parts of the mass. The cores so taken shall be thoroughly mixed and quartered and the triplicate samples for testing shall be taken from the material so drawn and prepared. A minimum quantity of 100 lb. shall be drawn for a unit of 30 tons of material with a proportionate quantity of material for multiples of this unit, provided that at no time shall less than 50 lb. be drawn as the original portion.

(*b*) *In Bulk* (At conveyors to or from bins, piles or cars, at packing machines, etc.)—Sampling at conveyors, packing machines, etc., shall conform to the provisions of Section 2 (*b*).

Powdered Material in Packages.

5. *In Packages.*—A sampling tube shall be used which takes a core not less than $\frac{1}{2}$ in. in diameter. The tube shall be so inserted into the package that it will take a core of the material being sampled from substantially the entire length of the package. Material thus taken from individual packages shall be thoroughly mixed and quartered, and the triplicate samples for testing shall be taken from the material so drawn and prepared. Individual packages shall be taken from various parts of the unit being sampled. At least 1.5 per cent of the packages shall be sampled, and in no case shall less than 5 packages be sampled.

D. Treatment of Sample at Laboratory

Sample for Chemical Analysis.

6. The sample as received at the laboratory shall be thoroughly mixed, and reduced in quantity by the usual methods of quartering to give a minimum portion of 75 g. This portion shall be ground, either by a suitable mechanical device, or by hand in an agate mortar, until it all passes a No. 100 sieve. It shall then be thoroughly mixed, placed in an air-tight container, and used in the determination of the chemical composition.

Samples for Special Tests.

7. Samples to be used for such special tests as may be required by individual specifications shall be obtained by mixing and quartering the material remaining after removal of the 75-g. portion for chemical analysis. The quantity of sample and the screen size of the particles will depend upon the requirements of the individual specifications.

II. INSPECTION

Inspection.

8. When inspection and sampling are to be conducted at the point of manufacture, the manufacturer shall afford the inspector representing the purchaser all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works. The duties of the inspector or sampler shall be confined exclusively to sampling and inspection of the finished material as ready for shipment, and shall not under any circumstances be construed to permit investigation of methods or processes of manufacture.

III. REJECTION

Rejection.

9. (*a*) Rejection of material based on failure to pass the tests prescribed in the specifications shall be reported within 10 days from the taking of the samples, and the cause for rejection shall be stated.

(*b*). The samples which represent rejected material shall be kept in air-tight, moisture-proof containers for at least 5 days from the date of the original test report.

IV. RETESTING

10. (*a*) Either of the contracting parties may make claim for a retest within five days of the date of the original test report. The expense of the retest shall be borne by the party demanding such retest. **Retesting.**

(*b*). Should the contracting parties be unable to reach a mutually satisfactory agreement based upon the results of the original test, the third sample of material shall be delivered unopened to a referee laboratory for test and the results of this referee test shall be binding on both parties.

V. PACKING

11. *Lump Lime.*—Lump lime may be shipped in bulk in carload lots, in wooden barrels or steel containers holding 180 lb. or 280 lb. net each, or in pasteboard cartons holding 90 lb. net each. **Packing.**

12. *Pulverized Lime.*—Pulverized lime may be shipped in bulk, in carload lots, or in cloth or paper bags.

13. *Hydrated Lime.*—Hydrated lime shall be shipped in cloth bags holding 100 lb. net each, or in paper bags holding 50 lb. net each.

VI. MARKING

14. Each shipment of material shall carry with it some means of identification, stating the particular contract on which the purchase and shipment were made. **Marking.**

15. Each package shall have legibly marked thereon, the net weight of its contents, the name of the manufacturer, the place of manufacture, and the brand name, if any. This marking shall comply with all requirements of the Federal Lime Barrel Act, entitled "An Act to Standardize Lime Barrels (Public No. 228-Congress-S 5425)," and with such other federal or state laws as may be applicable to the shipment in question.

16. In addition to the above information, the following guarantee may be marked on each package or shipment: "Guaranteed by (name of manufacturer) to meet the specifications of the American Society for Testing Materials" for (name of material).

TENTATIVE DEFINITIONS OF TERMS RELATING TO LIME[1]

Serial Designation: C 51 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1922; REVISED, 1924.

I.

Quicklime.—A calcined material, the major part of which is calcium oxide or calcium oxide in natural association with a lesser amount of magnesium oxide, capable of slaking with water.

Hydrated Lime.—A dry powder obtained by treating quicklime with water enough to satisfy its chemical affinity under the conditions of its hydration.

NOTE.—It consists essentially of calcium hydroxide or a mixture of calcium hydroxide and magnesium oxide and magnesium hydroxide.

In Bulk.—Lime or lime products are "in bulk" when it or they exist *en masse* in bins, in piles, or in transporting vehicles.

II. SIZES OF QUICKLIME

Lump Lime.—Quicklime as it comes from the kilns.

Lump Lime Screened.—Lump lime after forking or screening to remove the portion which will pass a ½-in. sieve.

Pulverized Lime.—Quicklime which will pass a ¼-in. sieve.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. R. P. Brown, Secretary of Committee C-7 on Lime, National Lime Association, 918 G St., N. W., Washington, D. C.

TENTATIVE DEFINITIONS OF TERMS RELATING TO THE GYPSUM INDUSTRY[1]

Serial Designation: C 11 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1916; REVISED, 1921, 1922, 1923, 1924

Accelerator.—Any material or substance which, when used in stucco, plaster, mortar, concrete, etc., will hasten set beyond the limit of testing error.

Aggregate.—Any inert material used as a filler in stucco, plaster, mortar, concrete, etc., without regard to its function as a binding material.

Binder.—Any fibrous material which will increase the cohesiveness of plaster and stucco while in its plastic state.

Cement.—Any material, or a mixture of materials (without aggregate) which, when in a plastic state, possesses adhesive and cohesive properties, and hardens in place. The word "cement" is used without regard to the composition of the material and does not define its use or location of use as do the words "stucco," "plaster" and "mortar."

Consistency.—The degree of wetness of a plastic mixture.

Calcined Gypsum.—Gypsum partially dehydrated by means of heat, having the chemical formula $CaSO_4 \cdot \frac{1}{2}H_2O$.

Crushed Gypsum.—Gypsum subjected to a primary crushing operation.

Gypsum.—Calcium sulfate, combined with two molecules of water, in crystallin form, having the chemical formula $CaSO_4 \cdot 2H_2O$.

Gypsum Plastering Sand.—The fine granular material naturally or artificially produced by the disintegration of rock containing not less than 80 per cent by weight of fine silica, feldspar, dolomite or calcite.

Lath.—A material whose primary function is that of a base or background for the reception of plaster or stucco. The word "lath" is used without regard to the composition of the material, defining only its use.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 844 Rush St., Chicago, Ill.

Mortar.—Any material used in a plastic state that can be trowelled, and becomes hard in place, uniting structural materials. The word "mortar" is used without regard to the composition of the material, defining its use as a bonding material, as contrasted with the words "stucco" and "plaster."

Plaster.—Any material used in a plastic state to form a hard covering for the interior surfaces, walls and ceilings, etc., of any building or structure. The word "plaster" is used without regard to the composition of the material, defining only its use and location of use, as contrasted with the words "stucco" and "mortar."

Plasticity.—The yielding property of a wet mixture to change of form.

Retarder.—Any material or substance which, when used in stucco, plaster, mortar, concrete, etc., will retard set beyond the limit of testing error.

Sized Gypsum.—Crushed gypsum of prescribed diameter of individual particles.

Stucco.—Any material used in a plastic state to form a hard covering for the exterior walls or other exterior surfaces of any building or structure. The word "stucco" is used without regard to the composition of the material, defining only its use and location of use, as contrasted with the words "plaster" and "mortar."

Wood Fiber.—A material produced by grinding or shredding wood.

TENTATIVE DEFINITION OF THE TERM SAND[1]

Serial Designation: C 58-24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Sand.—The fine granular material naturally or artificially produced by the disintegration or crushing of rock or slag.

NOTE.—When used without a qualifying adjective it is generally understood to mean a product of the natural disintegration of siliceous or calcareous rock. The size of particle and other physical characteristics should properly be taken care of in specifications and therefore no limits are mentioned in the definition.

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[1] Criticisms of this Tentative Definition are solicited and should be directed to Mr. L. R. Ferguson, Chairman of the Sub-Committee, of Committee E-8, on Sand, 1400 Land Title Building, Philadelphia, Pa.

TENTATIVE SPECIFICATIONS
FOR
IRON OXIDE AND IRON HYDROXIDE[1]

Serial Designation: D 84 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1924.

Scope.

1. These specifications cover iron oxide and iron hydroxide pigments of red and brown colors.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be very finely ground iron oxide or iron hydroxide or a mixture thereof. Siliceous minerals may be present and, if necessary, sufficient carbon pigment may be added to produce the desired color.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall conform to the following requirements:

	MAXIMUM.	MINIMUM.
Ferric oxide, per cent	...	30.0
Material other than ferric oxide, insoluble siliceous matter and loss on ignition, per cent	10.0	...
Coarse particles retained on a Standard No. 325 screen,[2] per cent	3.0	...

Organic coloring matters shall be absent.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.) the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

The color and color strength when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *Paste.*—The paste as received and three months thereafter shall not be caked in the container and shall break up readily in linseed oil to form a smooth paint of brushing consistency. It shall mix readily with linseed oil, turpentine or volatile mineral spirits, or any combination of these, without curdling.

The paste shall conform to the following requirements:

	MAXIMUM.	MINIMUM.
Pigment, per cent	72.0	68.0
Linseed oil, per cent	32.0	28.0
Moisture and other volatile matter, per cent	0.7	....
Coarse particles and skins (total residue retained on a Standard No. 325 screen,[1] based on pigment), per cent	3.5	....

Number of Tests.

4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

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[1] For determining coarse particles, screens 3 in. in diameter are recommended. The screen cloth is described as follows: No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent.

TENTATIVE METHODS
OF
TESTING OLEO-RESINOUS VARNISHES[1]

Serial Designation: D 154 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society, and is subject to annual revision.

ISSUED, 1924.

FLASH POINT

The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids (Serial Designation: D 56) of the American Society for Testing Materials.[2]

VISCOSITY

Viscosity shall be determined by comparison at 25° C. (77° F.) with secondary standards whose viscosity expressed in poises has been accurately determined at that temperature.

NOTE.—Gardner-Holdt tubes may be used. *See Circular No. 178*, Scientific Section, Paint Manufacturers' Association of the U. S.

WATER TEST

The varnish shall be poured on one of the standard tin panels and allowed to drain in a nearly vertical position and dry for 48 hours. The panel shall be placed in a beaker containing about 7 cm. (2.5 in.) of distilled water at room temperature (immersing the end of the panel which was uppermost during the drying) and left in water for 18 hours. The panel shall then be removed from the water, wiped carefully, and allowed to dry out at room temperature. The time required for whitening, if any, to disappear, shall be noted. The results of the water test shall be reported as follows:

(1) Not visibly affected.

(2) Whitening disappears within 20 minutes.

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[1] These Tentative Methods, when adopted as standard, will be added to the present Standard Methods of Testing Oleo-Resinous Varnishes (Serial Designation: D 154 - 24), 1924 Book of A.S.T.M. Standards.

Criticisms of these Tentative Methods are solicited, and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1924 Book of A.S.T.M. Standards.

(3) Whitening does not disappear in 20 minutes, but does disappear within 2 hours.

(4) Whitening does not disappear within 2 hours, but does disappear within 24 hours.

(5) Whitening does not disappear within 24 hours.

Blooming, which sometimes occurs on immersion, is considered as a degree of whitening.

TENTATIVE METHOD OF TEST
FOR
DETERMINATION OF WAX IN SHELLAC[1]

Serial Designation: D 29 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Dissolve 10 g. of dry shellac in 200 cc. of 190° proof specially denatured alcohol, formula No. 1 or No. 30, with agitation at a temperature of 24° C. ± 3° C.

Allow the solution to stand for several hours, preferably over night, in a tall cylindrical vessel, maintained at a temperature of 24° C ± 3° C., until the wax has settled to a small layer at the bottom of the container. Decant the clear solution through a 12.5-cm. folded filter paper, taking care not to disturb the wax layer. Finally, transfer the wax to the filter, using 25 cc. of the above alcohol at the prescribed temperature. Wash the container and the wax with four 15-cc. portions of the prescribed alcohol. The final washings should be colorless. Allow most of the alcohol to evaporate from the filter paper and dissolve the wax by pouring successive small portions of boiling chloroform (U. S. P.) through the paper. Also wash the container with boiling chloroform and pour on the filter.

Collect the filtrate, which should contain all of the wax, in a tared dish, evaporate the chloroform and dry to constant weight at 105° C. Weigh the wax residue and calculate the percentage of wax.

The removal of the wax from the filter paper can also be accomplished in any suitable continuous extraction apparatus.

In the case of shellac varnishes, dilute a weight of the sample, corresponding to 10 g. of non-volatile matter, with 200 cc. of alcohol and proceed exactly as described above.

NOTE.—Average commercial orange and dry-bleached shellac will contain about 4 to 5 per cent of wax. Average commercial dry-bleached refined shellac will be practically free from wax.

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[1] This Tentative Method of Test, when adopted as standard, will become a part of the present Standard Methods of Testing Shellac (Serial Designation: D 29 - 24), 1924 Book of A. S. T. M. Standards.

Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

TENTATIVE METHOD OF TEST
FOR
COARSE PARTICLES IN PAINT PIGMENTS[1]

Serial Designation: D 185 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

I. APPARATUS

1. The apparatus shall consist of a standard No. 325 sieve.[2] A standard No. 325 sieve for comparison purposes should be reserved in the laboratory. Whenever a new sieve is secured, a practical test of its accuracy should be made by running on it and on the standard sieve a pigment that has a considerable percentage of coarse particles. A reserve stock of such pigment should be kept for this purpose.

II. PROCEDURE

2. The sieve shall be weighed on an analytical balance, the weight being recorded in a figure carried to the third decimal place. The sieve shall then be wet on both sides with the liquid to be used for wash purposes.

3. The sample of the pigment to be tested shall be weighed. For most pigments 10 g. will be the proper quantity. For black pigments of low specific gravity, 2 g. will be sufficient. For pigments like Prussian blue and graphite, 3 g. are generally used. The weighed samples of pigment shall then be transferred to the sieve.

If the pigment is one that is difficult to wet with the wash liquid, the quantity weighed out should first be placed in a beaker containing some of a liquid that easily wets the pigment and that is miscible with the wash liquid. For example, if water is to be used as the wash liquid, alcohol may be used as the wetting medium. The pigment is then gently stirred with the wetting liquid and the contents of the beaker transferred to the sieve. Where small particles of pigment are retained on the stirring rod or walls of the beaker they may easily be removed with the brush.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Sieves 3 in. in diameter will be received by the U. S. Bureau of Standards for test. The cloth will be tested to determine whether or not it conforms to the specifications for cloth of the U. S. Standard Sieve Series. The specifications for the sieve frame are now being prepared. No. 325 cloth of the U. S. Standard Sieve Series should be made of wire 0.036 mm. (0.0014 in.) in diameter, a tolerance of 15 per cent under and 35 per cent over being allowed on this diameter. The average opening between adjacent parallel wires should be 0.044 mm. (0.0017 in.), the tolerance being 8 per cent with the additional limitation that the maximum opening shall not exceed 0.044 mm. by more than 90 per cent. Sieves whose cloth conforms to these specifications and whose frames are in accordance with specifications now in preparation will be marked with the letters "BS" and the year in which the test is made. A report will be issued for each sieve submitted, a nominal fee being charged for this test.

4. The sieve shall then be held under a tap delivering about 300 to 500 cc. of wash liquid per minute. By slightly shaking the sieve, the pigment will be rapidly carried through. A soft camel's hair brush may be used in aiding the operation. If the sieve is held at a slight angle so that the pigment will gradually collect at one edge during the washing process, and then rotated, the pigment may be brushed out rapidly, with no risk of clogging the screen.

5. After the majority of the finely divided portion of the pigment has passed through the sieve (from 2 minutes to 1 hour, according to kind of pigment), the sieve shall be placed in an 8-in. porcelain dish containing 250 cc. of the wash liquid. The sieve will thus be covered to a depth of about $\frac{1}{2}$ in. The pigment remaining on the sieve shall be brushed with a soft 1-in. camel's hair brush at the rate of two strokes per second during two periods of 10 seconds each. The sieve shall then be raised from the dish after each 10-second period to let the liquid on the sieve run through. The liquid in the dish should be changed after every two brushing periods described above. This operation shall be continued until typewritten letters can be read through a layer of the wash liquid 8 cm. thick, which is approximately the height of a filled 250-cc. beaker of the low-form (Griffin) type.

Occasionally pigments will be found that foam when water is used as the wash liquid. In such instances, during the last washing in the porcelain dish, the use of a liquid that breaks down the foaming and is readily miscible with water, such as alcohol, will usually overcome this difficulty.

6. The pigment particles adhering to the brush shall then be washed back onto the sieve and the water below the sieve wiped off. A few drops of alcohol and then of ether should be added to expedite drying. The screen shall be dried for one hour in an oven at 105° C., or on a radiator, cooled, weighed, and the percentage of coarse particles calculated.

7. For pigments requiring wash liquids such as turpentine, mineral spirits, or kerosene, the wash liquid shall be siphoned from a vessel onto the sieve, finishing with ether to remove the wash liquid adhering to the sieve.

TENTATIVE METHODS OF ROUTINE ANALYSIS OF TITANIUM PIGMENTS[1]

Serial Designation: D 186 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924.

GENERAL METHODS

SPECIFIC GRAVITY

1. True specific gravity shall be determined by Gardner's method.[2]

COLOR

2. To 5 g. of the sample add 1.5 cc. of linseed oil, rub up on a stone slab or glass plate with a flat-bottomed glass or stone pestle or muller to a uniform smooth paste. Treat in a similar manner 5 g. of the standard titanium pigment. Spread the two pastes side by side on a clear, colorless glass plate and compare the colors. If the sample is as white as, or whiter than the "standard," it passes this test.

COLOR STRENGTH

3. Weigh accurately 0.01 g. of lampblack, place on a large glass plate or stone slab, add 0.2 cc. of linseed oil and rub up with a flat-bottomed glass pestle or muller, then add exactly 10 g. of the sample and 2.5 cc. of linseed oil, and grind with a circular motion of the pestle or muller 50 times; gather up with a sharp-edged spatula and grind out twice more in a like manner, giving the pestle or muller a uniform pressure. Treat another 0.01 g. of lampblack in the same manner except that 10 g. of standard pigment is used instead of the 10 g. of the sample. Spread the two pastes side by side on a glass microscope slide and compare the colors. If the sample is as light or lighter in color than the "standard" it passes this test.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Standard Method of Test for Specific Gravity of Pigments (Serial Designation: D 153) of the American Society for Testing Materials, 1924 Book of A.S.T.M. Standards.

COARSE PARTICLES

4. Dry in an oven at 105 to 110° C., a No. 325 sieve, cool, and weigh accurately. Weigh 10 g. of the sample, wash with water through the sieve, breaking up all lumps either by gentle pressure with a pestle in a mortar, but not grinding, or with a brush on the sieve. After washing with water until all but the particles too coarse to pass the sieve have been washed through, dry the sieve for one hour at 105 to 110° C., cool, and weigh.

METHODS OF ANALYSIS

QUALITATIVE ANALYSIS

5. Place about 0.5 g. of the sample in a 250-cc. Pyrex glass beaker; add 20 cc. of concentrated H_2SO_4 and 7 to 8 g. of $(NH_4)_2SO_4$. Mix well and boil for a few minutes. The sample should go completely into solution; a residue denotes the presence of silica or siliceous matter. Cool the solution, dilute with 100 cc. of water, heat to boiling, let settle, filter, wash with hot 5-per-cent H_2SO_4 until free from titanium, and test the residue for lead, etc. Test the filtrate for calcium, zinc, iron, chromium, etc., by the regular methods of qualitative analysis. For the iron determination add to a portion of the filtrate 5 g. of tartaric acid, render slightly ammoniacal, pass in H_2S in excess, and digest at side of steam bath for a while. No precipitate indicates the absence of iron, nickel, cobalt, lead, copper, etc. A black precipitate readily soluble in dilute HCl denotes iron. For titanium, test a small portion of the original filtrate with hydrogen peroxide (a clear yellow-orange color should result) and another portion with metallic tin or zinc (a pale blue to violet coloration should result). Negative tests should be shown for sulfide sulfur, carbonates, and appreciable water-soluble matter.

MOISTURE

6. Place 1 g. of the sample in a wide-mouthed short weighing tube provided with a glass stopper. Heat with stopper removed for two hours at a temperature between 105 and 110° C. Insert stopper, cool, and weigh. The loss in weight is reported as moisture.

MATTER SOLUBLE IN WATER

7. Transfer 2.5 g. of the pigment to a graduated 250-cc. flask, add 100 cc. of water, boil for 5 minutes, cool, fill to mark with water, mix, and allow to settle. Pour the supernatant liquid through a dry filter paper and discard the first 20 cc. Then evaporate 100 cc. of the clear filtrate to dryness in a weighed dish, heat for one hour at 105 to 110° C., cool and weigh.

TITANIUM OXIDE

8. Transfer 0.5 g. of the dried sample to a 250-cc. Pyrex beaker, add 20 cc. of concentrated H_2SO_4 and 7 to 8 g. of ammonium sulfate. Mix well and heat on hot plate until fumes of sulfuric acid are evolved, and then continue the heating over a strong flame until solution is complete (usually requires not over five minutes of boiling) or it is apparent that the residue is composed of silica or siliceous matter. Caution should be observed in visually examining this hot solution. Cool the solution, dilute with 100 cc. of water, stir, heat carefully to boiling while stirring, let settle, filter through paper and transfer the precipitate completely to the paper. Wash the insoluble residue with cold 5-per-cent (by volume) H_2SO_4 until titanium is removed.

Dilute the filtrate to 200 cc. and add about 10 cc. of NH_4OH (sp. gr. 0.90) to lower the acidity to approximately 5-per-cent H_2SO_4 (by volume).

Wash out a Jones reductor[1] with dilute 5 per cent by volume H_2SO_4 and water, leaving sufficient water in the reductor to fill to the upper level of the zinc. (These washings should require not more than one or two drops of 0.1 *N* $KMnO_4$ solution to obtain a pink color.) Empty the receiver, and put in it 25 cc. (measured in a graduate) of ferric sulfate solution (see Reagents). Reduce the prepared titanium solution as follows:[2]

(1) Run 50 cc. of the 5-per-cent H_2SO_4 solution through the reductor at a speed of about 100 cc. per minute.

(2) Follow this with the titanium solution.

(3) Wash out with 100 cc. of 5 per cent H_2SO_4.

(4) Finally run through about 100 cc. of water. Care should be taken that the reductor is always filled with solution or water to the upper level of the zinc. Gradually release the suction, wash thoroughly the glass tube that was immersed in the ferric sulfate solution, remove the receiver, and titrate immediately with 0.1 *N* $KMnO_4$ solution. One cc. of 0.1 *N* $KMnO_4$ equals 0.00481 g. Ti or 0.00801 g. TiO_2. Run a blank determination, using the same reagents, washing the reductor as in the above determination. Subtract this permanganate reading from the original reading and calculate the final reading to titanium dioxide (TiO_2). This will include iron, chromium, arsenic, and any other substance which is reduced by zinc and acid. See Calculations below for reporting TiO_2.

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[1] Directions for preparing a Jones reductor may be found in Blair, "The Chemical Analysis of Iron," Eighth Edition, pp. 88–89, or Treadwell-Hall, "Analytical Chemistry," Vol. 2, Fifth Edition.

[2] Lundell and Knowles, "The Determination of Titanium by Reduction with Zinc and Titration with Permanganate," *Journal*, Am. Chemical Soc., Vol. 45, p. 2620 (1923).

BARIUM SULFATE

9. Ignite, cool, and weigh the precipitate of $BaSO_4$ obtained in separating the titanium in Section 8.

NOTE.—If sample is impure it may be necessary to purify this precipitate, using appropriate methods.

IRON OXIDE

10. Prepare a standard ferric solution containing 0.00001 g. of Fe per cubic centimeter (see Reagents). Weigh a 1-g. portion of the sample and treat as in Section 8. Transfer without filtering to a graduated 200-cc. flask, cool, fill to the mark with water, mix, let settle, and determine iron colorimetrically as follows: Filter through a dry filter paper, discarding the first 20 cc.; transfer 50 cc. of the clear filtrate to a clean 100-cc. Nessler tube or other comparator. Add a drop or two of 0.1 *N* $KMnO_4$ solution to oxidize any ferrous iron. The faint pink color should persist for at least 5 minutes. Add 10 cc. of KCNS or $(NH_4)CNS$ solution (see Reagents), dilute with water to 100 cc., and mix thoroughly. Compare the color immediately with a series of standards, prepared side by side with the sample, in similar tubes. Prepare the standards from the standard ferric solution so as to have a range of from 0.000005 g. Fe to 0.00004 g. Fe (0.5 to 4.0 cc.). Transfer the desired volumes of the standard ferric solution to 100-cc. Nessler tubes containing 50 cc. each of an acid solution (made up by dissolving 8 g. of $(NH_4)_2SO_4$ in water, adding 20 cc. of concentrated H_2SO_4, cooling, diluting with water to 200 cc., and mixing), add a drop of 0.1 *N* $KMnO_4$ solution (or sufficient to yield a pink color that will persist for 5 minutes), and then 10 cc. of the thiocyanate solution. Finally dilute all standards with water to 100 cc. and mix each thoroughly.

NOTE.—For a single sample it is more convenient to run the standard Fe solution from a burette into a Nessler tube, containing 50 cc. of acid solution (made by dissolving 8 g. of $(NH_4)_2SO_4$ in water, adding 20 cc. of concentrated H_2SO_4, cooling and diluting with water to 200 cc., and mixing), a drop of 0.1 *N* $KMnO_4$ solution, 10 cc. of the thiocyanate solution, and then dilute with distilled water until the depth of the color produced after diluting 100 cc. and mixing, exactly matches that of the sample. From the burette reading calculate the amount of Fe. When using standards, the color comparisons must be made immediately.

CALCULATIONS

11. Calculate the total iron found to Fe_2O_3 and report as such. Calculate the TiO_2 equivalent by multiplying the Fe_2O_3 result by the factor 1.003 and subtract this figure from the total TiO_2 as determined in Section 8 and report the remainder as TiO_2.

Report all results on the dry or moisture-free basis.

SOLUTION REQUIRED

12. *Decinormal Potassium Permanganate Solution.*—Dissolve 3.161 g. of pure $KMnO_4$ in 1 liter of distilled water, let stand 8 to 14 days, siphon off the clear solution (or filter through asbestos), and standardize as follows: In a 400-cc. beaker dissolve 0.25 to 0.30 g. (accurately weighed) of U. S. Bureau of Standards' sodium oxalate in 250 cc. of hot water (80 to 90° C.) and add 15 cc. of dilute H_2SO_4 (1:1). Titrate at once with the $KMnO_4$ solution, *stirring the liquid vigorously and continuously.* The $KMnO_4$ must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise with particular care to allow each drop to be fully decolorized before the next is introduced. The solution should not be below 60° C. by the time the end point is reached. (More rapid cooling may be prevented by allowing the beaker to stand on a small asbestos-covered hot plate during the titration. The use of a small thermometer as a stirring rod is most convenient.) The weight of sodium oxalate used multiplied by 0.8334 gives its iron equivalent, or multiplied by 1.1954 gives its titanium dioxide equivalent (International Atomic Weights, 1921–1922). The $KMnO_4$ solution should be kept in a glass-stoppered bottle painted black to keep out light.

Ferric Sulfate Solution for Titanium.—A solution containing 2 per cent of iron as ferric sulfate is desired and may be prepared as follows: Dissolve 20 g. of pure iron or plain carbon steel in a slight excess of HCl, oxidize with HNO_3, add about 80 cc. of H_2SO_4 and heat until fumes of the latter are evolved. Cool, dilute with water to 1000 cc., digest on a steam bath until sulfates are dissolved, and filter if necessary. Add 0.1 *N* $KMnO_4$ solution until a faint pink color persists for 5 minutes (to oxidize any ferrous iron that may be present).

Ferric ammonium sulfate may be used also.[1]

Standard Ferric Sulfate Solution for Colorimetric Determination of Iron.—Determine the strength of the ferric solution for the TiO_2 determination in terms of Fe and dilute a portion of this solution until one is obtained of the strength 1 cc. equals 0.00001 g. Fe.

Potassium Thiocyanate Indicator.—Prepare a 2-per-cent solution of the pure salt in distilled water.

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[1] Gooch, "Methods in Chemical Analysis," First Edition, p. 436.

TENTATIVE METHOD OF TEST
FOR
DISTILLATION OF GASOLINE, NAPHTHA, KEROSENE, AND SIMILAR PETROLEUM PRODUCTS[1]

Serial Designation: D 86 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1923, 1924.

APPARATUS

Flask. 1. *Flask.*—The Standard 100-cc. Engler flask is shown in Fig. 1, the dimensions and allowable tolerance being as follows:

	CENTIMETERS	INCHES	TOLERANCES, CM.
Diameter of bulb, outside	6.5	2.56	0.2
" " neck, inside	1.6	0.63	0.1
Length of neck	15.0	5.91	0.4
" " vapor tube	10.0	3.94	0.3
Diameter of vapor tube, outside	0.6	0.24	0.05
" " " " inside	0.4	0.16	0.05
Thickness of vapor tube wall	0.1	0.04	0.05

The position of the vapor tube shall be 9 cm. (3.55 in.) ± 3mm. above the surface of the liquid when the flask contains its charge of 100 cc. The tube is approximately in the middle of the neck and set at an angle of 75 deg. (tolerance ± 3 deg.) with the vertical.

Condenser. 2. *Condenser.*—The condenser (Fig. 2) consists of a $\frac{9}{16}$-in. (14.29 mm.) OD No. 20 Stubbs Gage seamless brass tube, 22 in. (55.88 cm.) long. It is set at an angle of 75 deg. from the perpendicular and is surrounded with a cooling bath 15 in. long (38.1 cm.), approximately 4 in. (10.16 cm.) wide by 6 in. (15.24 cm.) high. The lower end of the condenser tube is cut off at an acute angle, and curved downward for a length of 3 in. (7.62 cm.) and slightly backward so as to insure contact with the wall of the graduate at a point 1 to 1¼ in. (2.54 to 3.8 cm.) below the top of the graduate when it is in position to receive the distillate.

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[1] The revision in this tentative method consists essentially in the omission of the cotton from the thermometer bulb. Otherwise, the method is practically identical with that formerly published under the serial designation D 86 – 21 T.

Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

Shield.

3. *Shield.*—The shield (Fig. 2) is made of approximately 22 gage sheet metal and is 19 in. (48.26 cm.) high, 11 in. (27.94 cm.) long and 8 in. (20.32 cm.) wide, with a door on one narrow side, with two openings, 1 in. (2.54 cm.) in diameter, equally spaced, in each of the two narrow sides, and with a slot cut in one side for the vapor tube. The centers of these four openings are 8½ in. (21.59 cm.)

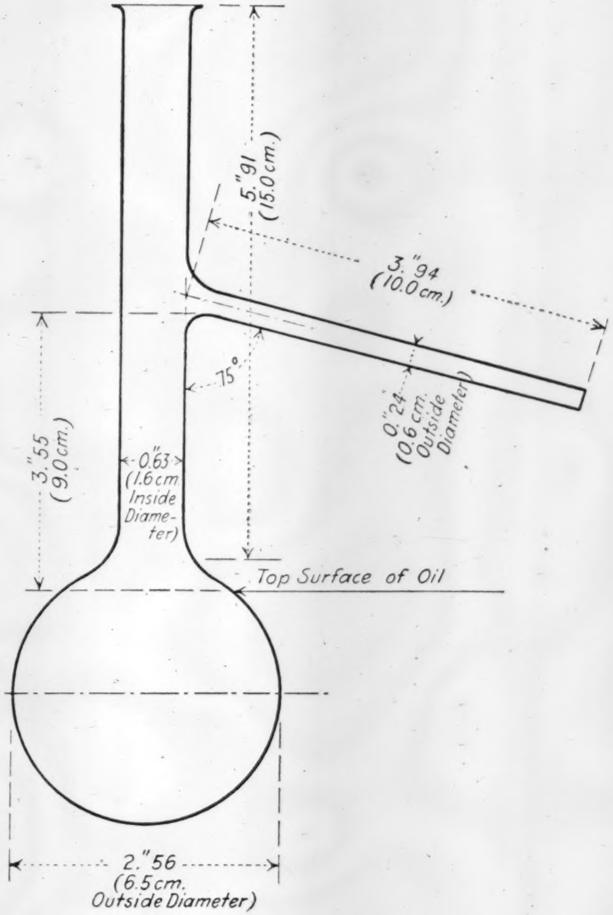
5.″91 (15.0 cm.)
3.″94 (10.0 cm.)
75°
0.″24 (0.6 cm. Outside Diameter)
3.″55 (9.0 cm.)
0.″63 (1.6 cm Inside Diameter)
Top Surface of Oil
2.″56 (6.5 cm. Outside Diameter)

FIG. 1.

below the top of the shield. There are also three $\frac{1}{2}$-in. (1.27 cm.) holes in each of the four sides with their centers 1 in. (2.54 cm.) above the base of the shield.

Support. 4. *Ring Support and Hard Asbestos Boards.*—The ring support is of the ordinary laboratory type, 4 in. (10.16 cm.) or larger in diameter, and is supported on a stand inside the shield. There are two hard asbestos boards: One 6 by 6 by $\frac{1}{4}$ in. (15.24 by 15.24 cm. by 6.35 mm.) with a hole $1\frac{1}{4}$ in. (3.175 cm.)[1] in diameter in its center, the sides of which shall be perpendicular to the surface; the other, an asbestos board to fit tightly inside the shield, with an opening 4 in. (10.16 cm.) in diameter concentric with the ring support. These are arranged as follows: The second asbestos board is placed on the ring and the first or smaller asbestos board on top so that it may be moved in accordance with the directions for placing the distilling flask. Direct heat is applied to the flask only through the $1\frac{1}{4}$-in. (3.175 cm.) opening in the first asbestos board.

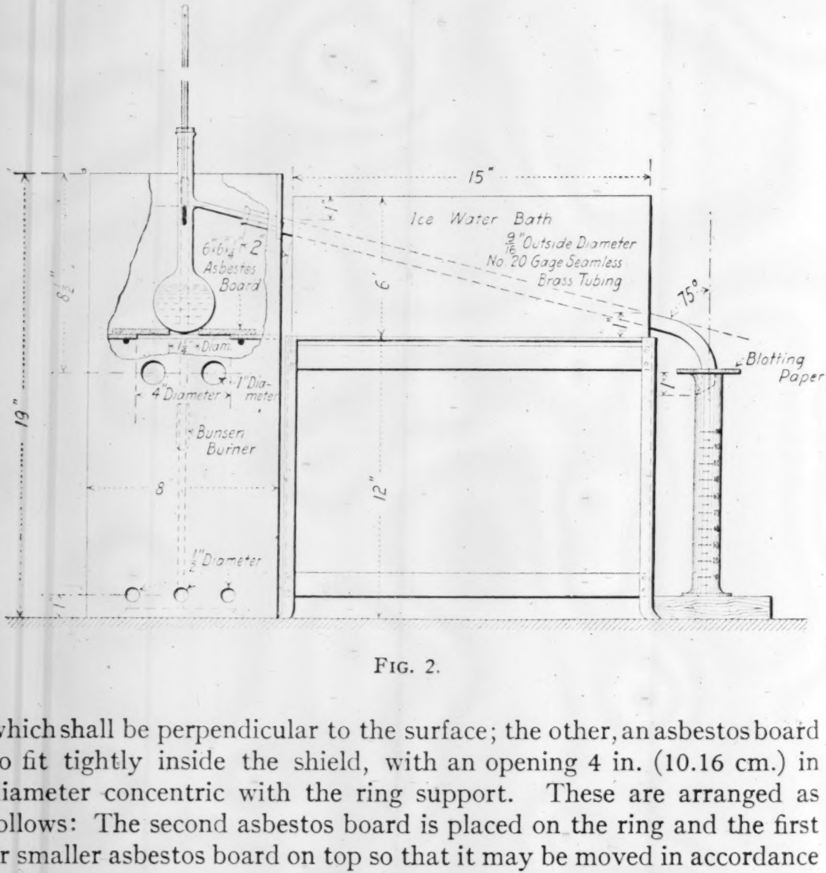
15"
Ice Water Bath
9/16" Outside Diameter
No. 20 Gage Seamless
Brass Tubing
6×6×1/4"×2"
Asbestes
Board
8 1/2"
19"
6"
1"
1"
75°
1 1/4" Diam.
4" Diameter
1" Diameter
Bunsen
Burner
8
12"
1/2" Diameter
Blotting
Paper
1"

FIG. 2.

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[1] When distilling petroleum products having an end point above 470° F. (243.34° C.), the hole in the asbestos board shall be $1\frac{1}{2}$ in. (3.81 cm.) in diameter.

5. *Gas Burner or Electric Heater.*— **Heater.**

(*a*) *Gas Burner.*—The burner is so constructed that sufficient heat can be obtained to distill the product at the uniform rate specified below. The flame should never be so large that it spreads over a circle of diameter greater than 3½ in. (8.89 cm.) on the under surface of the asbestos board. A sensitive regulating valve is a necessary adjunct, as it gives complete control of heating.

(*b*) *Electric Heater.*—The electric heater, which may be used in place of the gas flame, shall be capable of bringing over the first drop within the time specified below when started cold, and of continuing the distillation at the uniform rate. The electric heater shall be fitted with an asbestos board top ⅛ to ¼ in. (3.175 to 6.35 mm.) thick, having a hole 1¼ in. (3.175 cm.) in diameter in the center. When an electric heater is employed, the portion of the shield above the asbestos board shall be the same as with the gas burner but the part below the board may be omitted.

6. *Thermometers.*—

(*a*) The A.S.T.M. Low-Distillation Thermometer shall conform to the following requirements. These specifications cover a total-immersion thermometer graduated in either Centigrade or Fahrenheit degrees, as specified, the ranges being 0 to 300° C. or 30 to 580° F., respectively. **Thermometer.**

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 0 to 300° C. in 1° C. or 30 to 580° F. in 2° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass
Length, 10 to 15 mm. (0.39 to 0.59 in.).
Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 100 to 110 mm. (3.94 to 4.33 in.).

DISTANCE TO 300° C. OR 572° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 5° C. or 10° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Low Distillation," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.5° C. or 1° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50° C. or 100° F. up to 300° C. or 572° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature of 280 to 290° C. or 540 to 560° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear The marking: "A.S.T.M. Low Distillation, 0 to 300° C." or "A.S.T.M. Low Distillation, 30 to 580° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*b*) The A.S.T.M. High-Distillation Thermometer shall conform to the following requirements. These specifications cover a total-immersion thermometer graduated either in Centigrade or Fahrenheit degrees, as specified, the ranges being 0 to 400° C. or 30 to 760° F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 0 to 400° C. in 1° C. or 30 to 760° F. in 2° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 10 to 15 mm. (0.39 to 0.59 in.).
Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 25 to 35 mm. (0.98 to 1.38 in.).

DISTANCE TO 400° C. OR 752° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures and letters clear cut and distinct. The first and each succeeding 5° C. or 10° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. High Distillation" a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale up to 370° C. or 700° F. when the thermometer is standardized as provided below shall not exceed 1° C. or 2° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50° C. or 100° F. up to 370° C. or 700° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 and 370° C. or 680 and 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. High Distillation, 0 to 400° C." or "A.S.T.M. High Distillation, 30 to 760° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

Graduate.

7. *Graduate.*—The graduate shall be of the cylindrical type, of uniform diameter, with a pressed or molded base and a lipped top. The cylinder shall be graduated to contain 100 cc., and the graduated portion shall be not less than 7 in. (17.78 cm.) nor more than 8 in. (20.32 cm.) long. It shall be graduated in single cubic centimeters and each fifth mark shall be distinguished by a longer line. It shall be numbered from the bottom up at intervals of 10 cc. The distance from the 100-cc. mark to the rim shall be not less than $1\frac{1}{4}$ in. (3.175 cm.) nor more than $1\frac{3}{4}$ in. (4.445 cm.). The graduations shall not be in error by more than 1 cc. at any point on the scale.

PROCEDURE

Procedure.

8. (*a*) The condenser bath shall be filled with cracked ice,[1] and enough water added to cover the condenser tube. The temperature shall be maintained between 32 and 40° F. (0 and 4.45° C.).

(*b*) The condenser tube shall be swabbed to remove any liquid remaining from the previous test. A piece of soft cloth attached to a cord or copper wire may be used for this purpose.

(*c*) One hundred cubic centimeters of the product shall be measured in the 100-cc. graduated cylinder at 55 to 65° F. (12.78 to 18.33° C.) and transferred directly to the Engler flask. None of the liquid shall be permitted to flow into the vapor tube.

(*d*) The thermometer[2] provided with a cork shall be fitted tightly into the flask so that it will be in the middle of the neck and so that the lower end of the capillary tube is on a level with the inside of the bottom of the vapor outlet tube at its junction with the neck of the flask.

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[1] Any other convenient cooling medium may be used.

[2] For products having an initial boiling point of 212° F. (100° C.) or higher, the High-Distillation Thermometer shall be used; for all other products, the Low-Distillation Thermometer shall be used.

(*e*) The charged flask shall be placed in the $1\frac{1}{4}$-in. (3.175-cm.) opening in the 6 by 6-in. (15.24 by 15.24-cm.) asbestos board with the vapor outlet tube inserted into the condenser tube. A tight connection may be made by means of a cork through which the vapor tube passes. The position of the flask shall be so adjusted that the vapor tube extends into the condenser tube not less than 1 in. (2.54 cm.) nor more than 2 in. (5.08 cm.).

(*f*) The graduated cylinder used in measuring the charge shall be placed, without drying, at the outlet of the condenser tube in such a position that the condenser tube shall extend into the graduate at least 1 in. (2.54 cm.) but not below the 100-cc. mark. Unless the temperature is between 55 and 65° F. (12.78 and 18.33° C.) the receiving graduate shall be immersed up to the 100-cc. mark in a transparent bath maintained between these temperatures. The top of the graduate shall be covered closely during the distillation with a piece of blotting paper or its equivalent, cut so as to fit the condenser tube tightly.

Distillation. 9. When everything is in readiness, heat shall be applied at a uniform rate, so regulated that the first drop of condensate falls from the condenser in not less than 5 nor more than 10 minutes. When the first drop falls from the end of the condenser the reading of the distillation thermometer shall be recorded as the *initial boiling point.* The receiving cylinder shall then be moved so that the end of the condenser tube shall touch the side of the cylinder. The heat shall then be so regulated that the distillation will proceed at a uniform rate of not less than 4 nor more than 5 cc. per minute. The reading of the distillation thermometer shall be recorded when the level of the distillate reaches each 10-cc. mark on the graduate.

After the 90-per-cent point has been recorded, the heat may be increased because of the presence of the heavy ends which have high boiling points. However, no further increase of heat should be applied after this adjustment. The 4 to 5-cc. rate can rarely be maintained from the 90-per-cent point to the end of the distillation, but in no case should the period between the 90-per-cent and the end point be more than five minutes.

The heating shall be continued until the mercury reaches a maximum and starts to fall consistently. The highest temperature observed on the distillation thermometer shall be recorded as the ***maximum temperature*** or end point. Usually this point will be reached after the bottom of the flask has become dry.

The total volume of the distillate collected in the receiving graduate shall be recorded as the *recovery.*

The cooled residue shall be poured from the flask into a small cylinder graduated in 0.1 cc., measured when cool and the volume recorded as ***residue***.

The difference between 100 cc. and the sum of the recovery and the residue shall be calculated and recorded as *distillation loss*.

ACCURACY

10. With proper care and attention to detail, duplicate results obtained for initial boiling point and maximum temperature, respectively, should not differ from each other by more than 6° F. (3.33° C.). **Accuracy.**

TENTATIVE METHOD OF TEST
FOR
MELTING POINT OF PETROLATUM.[1]

Serial Designation: D 127 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

I. DEFINITION.

Definition. 1. *A.S.T.M. Petrolatum Melting Point.*—The temperature at which petrolatum becomes sufficiently fluid to leave the thermometer used in making the determination of melting point.

II. APPARATUS.

Thermometers. 2. (*a*) The melting point thermometer shall conform to the specifications for the A.S.T.M. paraffin wax melting point thermometer, as specified in Section 6 of the Standard Method of Test for Melting Point of Paraffin Wax (Serial Designation: D 87) of the American Society for Testing Materials.[2]

(*b*) The bath thermometer shall be of any suitable type accurate throughout the required range to 2° F.

Test Tubes. 3. The test tubes shall be 25 by 100 mm. in size, and shall be supplied with corks grooved at sides to permit air circulation and bored at the exact center to receive the thermometer.

Beakers. 4. The beakers shall be of the tall form type and have a capacity of 600 cc.

III. PROCEDURE.

Procedure. 5. (*a*) Samples of sufficient size that exactly represent the petrolatum under inspection shall be secured. The material shall be melted slowly in a casserole or other suitable dish with stirring until the temperature reaches 180° F. The source of heat shall then be removed and the petrolatum allowed to cool to 15° F. above the temperature that it is anticipated will be its melting point. The thermometer bulb shall be chilled to 40° F., wiped dry and while still cold thrust into the melted petrolatum so that approximately the lower half is submerged. It shall be withdrawn immediately, held vertically away from the heat until the surface dulls, and then placed in a water bath having a temperature not over 60° F. for five minutes.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

[2] 1924 Book of A.S.T.M. Standards.

(*b*) The thermometer shall be securely fixed in a test tube by means of a cork so that the lowest point is 15 mm. above the bottom of the test tube. The test tube shall be surrounded with a water bath at a temperature of 60° F. The temperature of the bath shall be raised at a rate of 2° F. per minute to 100° F., then at a rate of 1° F. per minute until the first drop of petrolatum leaves the thermometer. The temperature at this instant shall be recorded.

Melting Point.

6. If the variation of three such determinations does not exceed 2° F., the average of these three determinations shall be reported as the melting point of the sample under test. If the variation of three determinations is greater than 2° F., two additional determinations shall be made and the average of five determinations reported as the melting point.

TENTATIVE METHOD OF ANALYSIS OF GREASE.[1]

Serial Designation: D 128 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

Scope.

1. These methods of analysis permit determinations sufficiently accurate for referee purposes of all the constituents of greases likely to be covered by specifications. These constituents are fillers and ash, soap bases, soap, fat, water, excess alkali or acid, petroleum products and unsaponifiable matter. No quantitative determination of glycerin is described, but a procedure is outlined for its qualitative detection.

I. SAMPLE.

Sample.

2. The size of sample for the soap determination (Methods (1) and (2) for Determination of Fillers, Soap, Fat, Petroleum Oil and Unsaponifiable Matter) shall be from about 8 to 30 g., depending on the consistency of the grease, which is chiefly determined by the percentage of soap present. Ten to twenty grams is usually a convenient amount for No. 3 Cup Grease, while thin transmission and other greases require a larger sample. The original sample should be stirred or mixed until uniform.

Accuracy of Weighing.

3. Samples need not be weighed more closely than 0.1 g.

II. SOLVENTS.

Petroleum Ether.

4. The petroleum ether shall have an end point not higher than 200° F., and 125 cc. of it shall not consume more than 0.2 cc. of 0.5 *N* potassium hydroxide when a blank test is made as follows:

One hundred and twenty-five cubic centimeters of petroleum ether shall be boiled with 10 cc. of 0.5 *N* alcoholic potassium hydroxide and 50 cc. of neutral 50-per-cent alcohol for $1\frac{1}{2}$ hours on a hot plate, using a glass tube of about 7 mm. internal diameter and 75 cm. long as a reflux condenser. After cooling, the solutions shall be titrated with 0.5 *N* hydrochloric acid and phenolphthalein. Not less than 9.8 cc. of 0.5 N acid shall be required for neutralization. The amount of alkali consumed in this test shall be deducted as a blank correction in the fat determination on solution (E).[1]

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

Alcohol. 5. The alcohol shall be prepared from commercial 95-per-cent grain or denatured grain alcohol by distilling from sodium hydroxide, diluting to 50 per cent (or 70 per cent) by volume with distilled water and neutralizing exactly with sodium or potassium hydroxide and phenolphthalein.

Phenolphthalein. 6. The phenolphthalein solution shall be prepared by dissolving 1.0 g. of phenolphthalein in 50 cc. of strong redistilled alcohol, adding 50 cc. of water, and neutralizing with sodium or potassium hydroxide.

Hydrochloric Acid. 7. Concentrated c.p. hydrochloric acid shall be used when "concentrated hydrochloric acid" is specified. Hydrochloric acid, 10-per-cent, shall contain 10 per cent by weight of absolute HCl, with a permissible variation of ± 0.5 per cent.

III. PROCEDURE.

(*A*) *Determination of Ash.*

NOTE.—The determination of the total ash should not in general be regarded as of any great importance. It is, however, sometimes required. This determination is often unsatisfactory on account of interaction between sodium carbonate derived from the soap, and inorganic fillers. There is always likelihood of reaction with the porcelain crucible itself on account of the long continued heating necessary to burn out all carbon. Moreover, if much sodium or potassium carbonate is present, the ash is fusible and often encloses carbon, making complete removal of the latter very difficult. Results will always be low in the presence of easily reducible oxides of volatile metals. There is also uncertainty as to when calcium carbonate has been completely ignited to calcium oxide. Ash determinations made on the same sample in different laboratories are likely to vary widely. For these reasons, it is usually preferable to make separate determinations of the percentage of fillers and of soap, from which data a calculation is easily made giving all the information to be gained from a direct determination of total ash.

8. The percentage of ash shall not be included in the total of the analysis.

(*1*) *Rapid Routine Method of Ash Determination.*

9. From 2 to 5 g. of grease shall be placed in a weighed porcelain crucible, and the sample weighed to the nearest 0.1 g. If lead or zinc soap is known to be absent, a platinum crucible is more convenient. The combustible matter shall be burned off slowly and the residue finally ignited until the ash is free of carbonaceous matter. The crucible and contents shall then be cooled in a desiccator and weighed, reporting the result as percentage of ash.

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[1] Solutions designated by capital letters in parentheses refer to the solutions given in Fig. 1.

(2) Alternative Method of Ash Determination.

Ash, Alternative.

10. The sample shall be burned as in method (1) until the ash is nearly free from carbon. The crucible and contents shall then be cooled, the soluble portions dissolved in a little water, and a slight excess of dilute sulfuric acid added, running the acid in carefully from a pipette inserted under a small watch glass covering the crucible. The crucible and contents shall then be warmed on the steam bath until effervescence has ceased. The watch glass shall then be rinsed with water into the crucible. The solution when tested with methyl orange for free acidity shall show free acid present. The contents of the crucible shall be evaporated to dryness, and the whole ignited at a low red heat, adding a few small pieces of dry ammonium carbonate to drive off the excess of sulfur trioxide. After cooling and weighing, the result shall be reported as "percentage of ash as sulfates."

The alternative method gives more concordant results than the first method, but requires more time and manipulation.

(B) Qualitative Examination of Ash.

Detection of Bases.

11. An easily fusible ash, dissolving completely in water to give a strongly alkaline solution, indicates a grease containing sodium, potassium, or both. A white infusible ash, practically insoluble in water, but imparting to it an alkaline reaction, may indicate calcium, with or without magnesium or aluminium. Zinc is shown by the yellow color of the ash while hot, and lead may be indicated by the presence of metallic globules, or by the yellow color of the ash when cold.

12. The ash shall be dissolved in dilute nitric or hydrochloric acid, and the presence of the several bases confirmed by suitable chemical tests, any standard scheme of qualitative analysis being followed.

(C) Quantitative Examination of Ash.

13. For the quantitative examination of ash any standard analytical procedure shall be used, the choice of methods being based on the information gained from the qualitative tests. If only one base is present, a quantitative determination is in general unnecessary.

(D) Determination of Fillers, Soap, Fat, Petroleum Oil and Unsaponifiable Matter.

Choice of Method.

14. Cup, fiber and sponge greases, with or without graphite, and all comparatively light colored greases, including axle greases,

shall be examined by method (1). Dark greases containing residuum, asphaltic oils and asphalt, tars, etc., shall be examined by method (2), as these ingredients usually cause stubborn emulsions if a shaking out process is applied at the start.

(1) Determination of Filler, Soap, Fat, Etc.

Determination of Filler

15. If no fillers are present, Sections 15 and 16 shall be passed over and the grease sample introduced directly from a weighing bottle into a separator, the weight of the sample being obtained by difference. (See Section 2.) The sample shall then be shaken with 75 cc. of petroleum ether and 50 cc. of 10-per-cent hydrochloric acid until the grease is completely decomposed, after which Section 17 shall be followed. If fillers are present, the sample (See Section 2) shall be weighed in a small beaker, 50 cc. of 10-per-cent hydrochloric acid added and the beaker warmed on the steam bath, stirring until all soap lumps have disappeared and the upper layer is clear. If undissolved mineral matter or other filler is present, both layers shall be filtered through a Gooch crucible provided with a suitable mat, the beaker and crucible washed with water and petroleum ether, and the crucible finally washed with strong alcohol, collecting the alcohol washings separately and discarding them. The crucible and contents shall then be dried at 120° C. and weighed, and the result reported as "percentage of insoluble matter" (graphite, mica, talc, asbestos, gypsum, wood pulp, etc.)

Determination of Gypsum.

16. If gypsum is present as a filler, the results obtained in the determination described in Section 15 will be too low because of the solubility of calcium sulfate in hydrochloric acid. A sample of about 5 g. of grease shall be weighed in a small beaker, and decomposed with 50 cc. of petroleum ether and 25 cc. of concentrated hydrochloric acid, warming on the steam bath until all gypsum is dissolved. The contents of the beaker shall be cooled and poured into a separatory funnel, the beaker rinsed with water and a little petroleum ether and the solutions in the funnel allowed to separate clearly. The lower layer shall then be drawn into a beaker, and the petroleum ether in the separator washed with two portions of 20 cc. each of 10-per-cent hydrochloric acid, adding the washes to the strong acid solution in the separator. The hydrochloric acid solution in the beaker shall then be evaporated on the steam bath almost to dryness, diluted to 150 cc. with water, heated to boiling and treated with 10 cc. of 10-per-cent barium chloride solution. The barium sulfate shall then be filtered off and ignited in the usual way, and from the weight of the barium sulfate, the percentage of calcium sulfate shall be calculated, reporting it as $CaSO_4 \cdot 2H_2O$.

NOTE.—Chalk and other forms of alkaline earth carbonates are not determined by this method, but are considered under the determination of free alkalinity, Section 24.

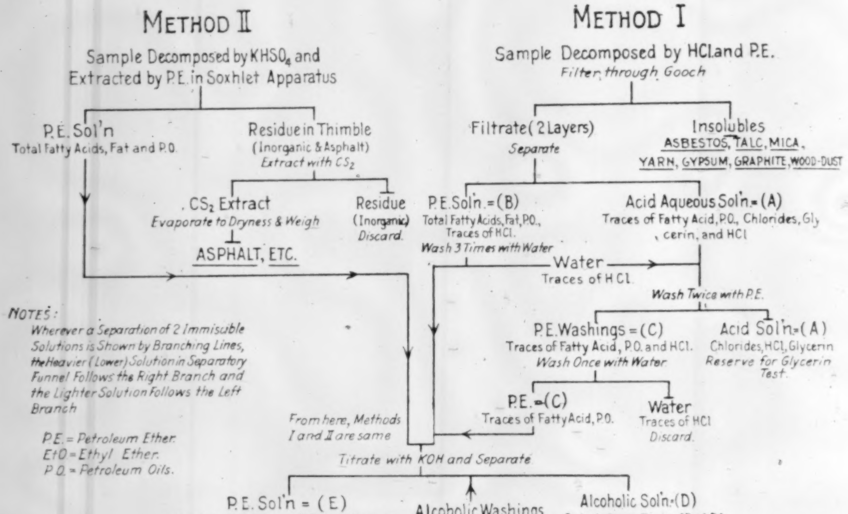
METHOD II
Sample Decomposed by KHSO₄ and Extracted by P.E. in Soxhlet Apparatus
P.E. Sol'n
Total Fatty Acids, Fat and P.O.
Residue in Thimble
(Inorganic & Asphalt)
Extract with CS₂
CS₂ Extract
Evaporate to Dryness & Weigh
ASPHALT, ETC.
Residue
(Inorganic)
Discard.
METHOD I
Sample Decomposed by HCl and P.E.
Filter through Gooch
Filtrate (2 Layers)
Separate
Insolubles
ASBESTOS, TALC, MICA, YARN, GYPSUM, GRAPHITE, WOOD-DUST
P.E. Sol'n. = (B)
Total Fatty Acids, Fat, P.O., Traces of HCl.
Wash 3 Times with Water
Acid Aqueous Sol'n. = (A)
Traces of Fatty Acid, P.O., Chlorides, Glycerin, and HCl
Water
Traces of HCl.
Wash Twice with P.E.
P.E. Washings = (C)
Traces of Fatty Acid, P.O. and HCl.
Wash Once with Water
Acid Sol'n. = (A)
Chlorides, HCl, Glycerin
Reserve for Glycerin Test.
P.E. = (C)
Traces of Fatty Acid, P.O.
Water
Traces of HCl
Discard.
NOTES:
Wherever a Separation of 2 Immiscible Solutions is Shown by Branching Lines, the Heavier (Lower) Solution in Separatory Funnel Follows the Right Branch and the Lighter Solution Follows the Left Branch
P.E. = Petroleum Ether.
EtO = Ethyl Ether.
P.O. = Petroleum Oils.
From here, Methods I and II are same
Titrate with KOH and Separate
P.E. Sol'n = (E)
Fat, P.O., and Traces of Potash Soaps
Wash 3 Times, with 50% Alcohol.
Alcoholic Washings
Traces of Soaps, Fat and P.O.
Alcoholic Sol'n. = (D)
Potash, Soaps, Traces of Fat & P.O.
Place in Separator, Wash Once with P.E.
P.E. Washings
Traces of Fat and P.O.
Alcoholic Sol'n. = (D)
Potash Soaps
Evaporate in Beaker, Dissolve in Hot Water, Acidify, Shake out twice with EtO
P.E. Sol'n. = (E)
Fat and P.O.
Saponify with KOH, Titrate and Separate
EtO. Sol'n. = (F)
Fatty Acid and Traces HCl.
Wash Twice with Water.
Acid Water
KCl, HCl.
Discard.
P.E. Sol'n. = (G)
P.O., Traces of Soap.
Wash Twice with 50% Alcohol
Alcoholic Sol'n. = (H)
Potash Soaps, Traces of P.O.
Alcoholic Washings = (I)
Traces of Soap
Wash Once with P.E.
EtO. Sol'n. = (F)
Evaporate to Dryness and Weigh.
FREE FATTY ACID & FATTY ACID FROM SOAP
Water
HCl.
Discard.
P.E. Sol'n. = (G)
P.O. and Unsapon.
P.E. Washings.
Traces of P.O.
Alcoholic Sol'n. = (H)
Potash Soap from Fat.
Evaporate Alcohol, Dissolve in Water, Acidify, Shake out 3 Times with P.E.
Evaporate to Dryness and Weigh.
PETROLEUM AND UNSAPONIFIABLE
Petroleum Ether
Evaporate to Dryness & Weigh
FATTY ACID FROM FAT
Acid Water
KCl, HCl.
Discard.

FIG. 1.—Scheme of Grease Analysis.

Determination of Soap.

17. The solution resulting from the decomposition of the filler-free grease or the combined filtrate and washes from the determination of fillers (Section 15), except the alcohol, which is discarded, shall be placed in a separator, allowed to clear, and the aqueous layer (*A*),[1]

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[1] Solutions designated by capital letters in parentheses refer to the solutions given in Fig. 1.

which contains all the bases as well as glycerin, shall be drawn into another separator. The petroleum ether layer (*B*) shall be washed three times with 25cc. of water to remove hydrochloric acid, adding the washings to (*A*). Solution (*B*) shall then be run into a 250-cc. separator. The aqueous solution (*A*) shall then be washed twice with 20 cc. of petroleum ether (*C*), whereupon (*A*) is set aside for examination for glycerin (see Section 18). Solution (*C*) shall then be washed once with 15 cc. of water, which is rejected, and (*C*) shall be added to (*B*). If (*B*) and (*C*) are comparatively light colored, an approximate determination of free fatty acids and fatty acids from soap may now be made by titrating the solution in the separator with 0.5 *N* alcoholic potassium hydroxide and phenolphthalein, using 200 as the average neutralization value of the fatty acid (that is, 1.0 g. of fatty acid requires 200 mg. of absolute KOH for neutralization). If solutions (*B*) and (*C*) are dark, a few drops of phenolphthalein and sufficient 0.5 *N* alcoholic potassium hydroxide shall be added to make the alcoholic layer distinctly alkaline after vigorous shaking. If the solutions have been titrated, a slight excess of alkali shall be added before separating. The conservative addition of strong alcohol at this point may aid in securing rapid and sharp separation. The two solutions shall be allowed to separate sharply and the lower alcoholic layer (*D*) drawn off into another separator. The upper petroleum ether layer (*E*) shall be washed three times, with 30, 25 and 20 cc. of neutral 50-per-cent alcohol respectively, adding these washes to (*D*). Solution (*D*) shall be washed with 25 cc. of petroleum ether, after which (*D*) is drawn off into a beaker, and the petroleum ether added to (*E*). Solution (*D*) shall then be evaporated to a small volume to remove alcohol, the residue of potassium soap washed into a separator with hot water, acidified with hydrochloric acid and shaken out twice with 50 and 25 cc. of ethyl ether (*F*), respectively. Solution (*F*) shall be run into another separator and washed twice with 20-cc. portions of water, which is discarded. Solution (*F*) shall then be transferred to a weighed beaker and evaporated to dryness on the steam bath, blowing with air to remove all traces of petroleum ether. The residue consisting of free fatty acid and fatty acid from soap shall be heated for a short time on a steam bath, adding and evaporating 5 cc. of absolute alcohol to remove the last traces of water, and weighed. The exact neutralization value shall then be determined on as large a sample of these fatty acids as possible. From the total fatty acid found here, the free acid if any (see Sections 23 and 25) shall be deducted and the remainder calculated to percentage of soap, using the ash analysis as a guide in distributing the bases, if more than one are present.

The fatty acids may be identified to some extent by special tests, such as odor, crystal form, melting point, iodine number, neutralization value, color reactions, etc.

If the grease is appreciably oxidized, the fatty acids obtained by the ethyl ether extraction are likely to be dark in color and hard to identify. For further study and identification, the neutralized acids may be extracted again (qualitatively) with petroleum ether and dilute HCl, thus eliminating the small amount of more darkly colored matter.

Detection of Glycerin.

18. In case it is desired to determine whether a grease has been made from whole fats or from fatty acids, solution (*A*) shall be neutralized with dry sodium carbonate and sufficient excess added to precipitate calcium or other metals. The whole mass shall then be evaporated to dryness, the residue extracted several times with strong alcohol, the combined alcoholic extracts filtered, and the alcohol evaporated. The residue will then contain most of the glycerin, with a little sodium chloride. The presence or absence of glycerin in the residue shall be confirmed by suitable qualitative tests.

Since fats on saponification yield between 10 and 11 per cent of glycerin, and this analytical scheme does not include a quantitative determination of glycerin, the total percentages in greases made from fats should always be less than 100.

Determination of Fat.

19. The petroleum ether solution (*E*) (Section 17), containing free fat, petroleum oils, and unsaponifiable matter shall be concentrated to a volume of about 125 cc. in a 300-cc. Erlenmeyer flask, 10 cc. of 0.5 *N* alcoholic potassium hydroxide and 50 cc. of strong neutral alcohol added, and the whole boiled on a hot plate with an air condenser for $1\frac{1}{2}$ hours. The uncombined alkali shall be titrated with 0.5 *N* hydrochloric acid, and from the alkali consumed, corrected for the blank determination as specified in Section 4, the percentage of free fat shall be calculated, using 195 as the average saponification value (that is, 1.0 g. of fat requires 195 mg. of absolute KOH for saponification.)

The titrated solution (*G*) shall be placed in a separator, the alcoholic lower layer (*H*) drawn off into another separator and the remaining traces of soap removed as described for (*B*) and (*C*), Section 17, making only two washes with 30 and 20 cc. of 50-per-cent alcohol (*I*). Solutions (*H*) and (*I*) shall be combined, washed once with a little petroleum ether, which is added to solution (*G*), and solutions (*H*) and (*I*) then evaporated to a small volume and the fatty acid isolated as described for (*D*), Section 17. The percentage of fat may be checked by weighing and titrating the free fatty acid.

Determination of Petroleum Oil.

20. The petroleum ether solution (*G*), now containing all the hydrocarbon oils and unsaponifiable matter shall be evaporated to dryness in a weighed beaker as described for (*F*), Section 17, the residue weighed, and the result reported as "petroleum oils plus unsaponifiable matter."

An approximate determination of the viscosity of the petroleum oil may be made by using a 2 or 5-cc. pipette, which has been standardized against oils of known viscosities. If a complete characterization of the petroleum products is required, a new sample of from 150 to 200 g. of grease shall be decomposed as described above, except that all quantitative operations shall be omitted, as well as the isolation of the free fatty acids, and the use of standard alkali and acid is not necessary.

If the grease contains rosin oil, beeswax, de gras, spermaceti, spermatin, montan wax, candle pitch, and other materials containing a large amount of unsaponifiable substances, the petroleum oils isolated from solution (*G*) will contain the unsaponifiable matter, and the constants found will differ from those of the petroleum products used in making the grease. In most cases, no further separation is possible except in the hands of skillful and experienced operators who can devise special methods to suit the individual conditions.

(2) Determination of Filler, Soap, Fat, Etc.

Method for Dark Greases.

21. The sample shall be weighed in a 3-in. porcelain dish, 10 g. of granulated acid potassium sulfate added and 10 g. of clean dry ignited sand. The dish and contents shall be heated on the steam bath with frequent stirring until all water is driven off, two hours usually being sufficient. After cooling and breaking up lumps with a small pestle, the mixture shall be transferred quantitatively to an extraction thimble, using a little petroleum ether to wash the last traces into the thimble, which should be already placed in a Soxhlet apparatus. The thimble shall be extracted thoroughly with petroleum ether, the extract concentrated somewhat if necessary, and the free fatty acid and fatty acid from soap titrated with 0.5 *N* alcoholic potassium hydroxide as in solutions (*B*) and (*C*), in method (1), Section 17. From this point on, the procedure is identical with that given in method (1), Sections 17, 19 and 20.

Determination of Asphalt and Tarry Matter.

22. The thimble shall be extracted a second time with carbon disulfide, the extract evaporated to dryness, heated for one hour to 120° C. and weighed, the results being reported as asphaltic and tarry matter. The residue in the thimble shall be discarded.

(*E*) *Determination of Free Alkali and Free Acid.*

Free Alkali. 23. From 10 to 30 g. of grease shall be weighed in a small beaker, dissolved as completely as possible in 75 cc. of petroleum ether by stirring with a spatula, the mixture washed into a 250-cc. Erlenmeyer flask with a small amount of petroleum ether, and the beaker rinsed with 50 cc. of 70-per-cent alcohol, the alcohol being poured into the flask, after which a few drops of phenolphthalein solution shall be added and the whole shaken vigorously. If the alcoholic layer, after settling for a few seconds, is pink, 10 cc. of 0.5 *N* hydrochloric acid shall be added, the solutions boiled on a hot plate for ten minutes to expel carbon dioxide, and the excess acid titrated back with 0.5 *N* alcoholic potassium hydroxide. The free alkalinity shall be calculated in terms of hydroxide of the predominating base.

Insoluble Carbonates. 24. If chalk or any other form of alkaline earth carbonate, or lead carbonate, is present as a filler, it will be detected by effervescence on adding the hydrochloric acid. As the amount of such carbonates is likely to be considerable, the volume of 0.5 *N* hydrochloric acid added shall be increased sufficiently to dissolve all carbonate and leave a slight excess of acid. The solution shall be boiled for two minutes and the excess acid titrated back with 0.5 *N* alcoholic potassium hydroxide, and from the acid consumed, its equivalent in calcium carbonate, etc., shall be calculated, disregarding any other forms of alkalinity which may have been present.

Free Acid. 25. If the original alcoholic layer is not pink, the solution shall be titrated carefully in the cold with 0.5 *N* alcoholic potassium hydroxide, shaking well after each addition. The acidity shall be calculated as oleic acid.

26. If soaps of iron, zinc, aluminium, or other weak bases are present, a determination of free acid is not possible, since these metallic soaps react with potassium hydroxide. Up to the present, no means has been devised whereby this determination can be made directly.

(*F*) *Determination of Water.*

Water. 27. The quantity of water shall be determined in accordance with the Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95) of the American Society for Testing Materials.[1]

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE METHODS OF TEST
FOR
VISCOSITY OF PETROLEUM PRODUCTS AND LUBRICANTS[1]

Serial Designation: D 88 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1921; REVISED, 1923; 1924.

Choice of Instrument.

1. (*a*) Viscosity shall be determined by means of the Saybolt Universal or Saybolt Furol Viscosimeter.

(*b*) In general, the Saybolt Universal Viscosimeter shall be used for lubricants and the Saybolt Furol Viscosimeter for fuel oils and other oils of similar viscosity.

TABLE I.—DIMENSIONS OF OIL TUBES.

Dimensions	Saybolt Universal Viscosimeter			Saybolt Furol Viscosimeter		
	Minimum, cm.	Normal, cm.	Maximum, cm.	Minimum, cm.	Normal, cm.	Maximum, cm.
Inside diameter of outlet tube	0.1750	0.1765	0.1780	0.313	0.315	0.317
Outside diameter of outlet tube at lower end.	0.28	0.30	0.32	0.40	0.43	0.46
Length of outlet tube[1]	1.215	1.225	1.235	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube[1]	12.40	12.50	12.60	12.40	12.50	12.60
Outside diameter of overflow rim, at the top[1,b]	[a]	....	3.30	[a]	....	3.30
Diameter of container[1]	2.955	2.975	2.995	2.955	2.975	2.995
Depth of cylindrical part of container[1]	8.8	....	....	8.8	....	....

[1] This dimension is identical in the Saybolt Universal and the Saybolt Furol instruments.

[a] The minimum value shall preferably be not less than 3.2 cm.

[b] The section of overflow rim must show a straight line from the outside of rim at top to the bottom of gallery.

(*c*) The Saybolt Universal Viscosimeter shall not be used for times of flow less than 32 seconds.

I. APPARATUS

Viscosimeters.

2. (*a*) The Saybolt viscosimeters (see Fig. 1) are made entirely of metal. The oil tube, *A*, is fitted at the top with an overflow cup, *B*, and the tube is surrounded by a bath. At the bottom of the oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask, Fig. 2, whose capacity at 20° C. (68° F.) to a mark on its neck is 60, ±0.15, cc. The outlet tube is of hard and non-

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

corrosive metal such as stainless steel, monel metal, etc. The inside diameter of neck of flask, at the level where the graduation mark is placed, is 0.8 to 1.1 cm. The lower end of the outlet tube is enclosed by a larger tube, which when stoppered by a cork, *C*, acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped string may be attached to the lower end of the cork as an aid to its rapid removal. The temperatures in the oil tube and in the bath are shown by thermometers. The bath may be heated by any suitable means. The oil tube shall be thoroughly cleaned, and all oil entering the oil tube shall be strained through a 100-mesh wire strainer. A stop watch shall be used for taking the time of flow of the oil and a pipette shall be used for draining the overflow cup.

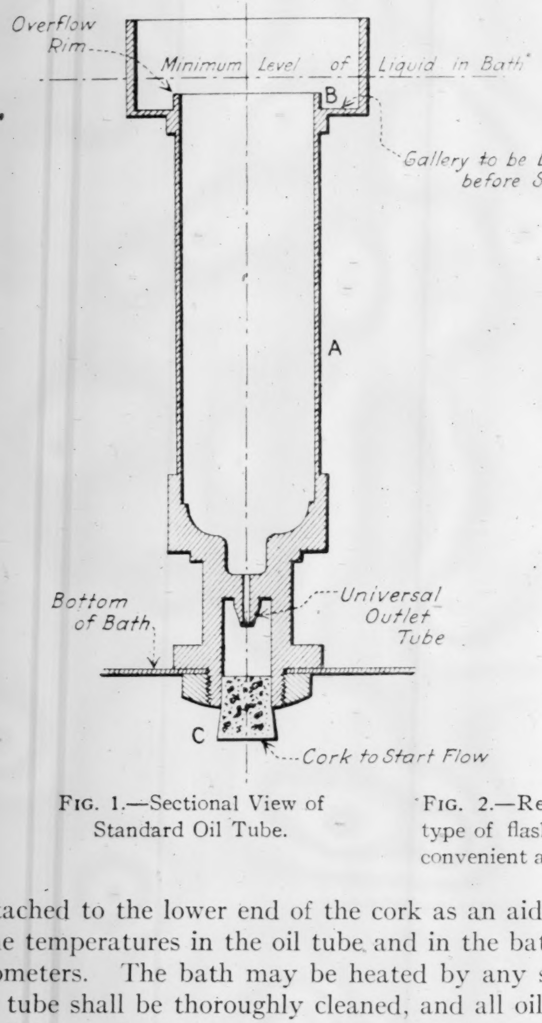
Overflow Rim
Minimum Level of Liquid in Bath
B
Gallery to be Drained before Starting Flow
A
Bottom of Bath
Universal Outlet Tube
C
Cork to Start Flow

FIG. 1.—Sectional View of Standard Oil Tube.

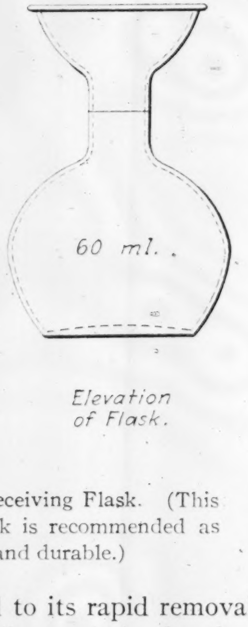
60 ml.
Elevation of Flask.

FIG. 2.—Receiving Flask. (This type of flask is recommended as convenient and durable.)

Oil Tube. (*b*) The oil tubes, which may be standardized by the U. S. Bureau of Standards, shall conform to the dimensions given in Table I. The time of flow shall be within ± 1 per cent of the time as obtained with the Bureau of Standards' master tube.[1]

Thermometers. (*c*) The bath and oil tube thermometers shall conform to the following requirements. They cover two sets of 4 thermometers each, one set being graduated in Fahrenheit degrees and the other set in Centigrade degrees, the ranges being chosen to include the temperatures commonly used in testing.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGES AND SUBDIVISIONS:

Range 66– 80° F., subdivision in 0.2° F. for tests at 77° F.
" 94–108° F., " 0.2° F. " 100° F.
" 120–134° F., " 0.2° F. " 122 and 130° F.
" 204–218° F., " 0.2° F. " 210° F.

or

Range 19–27° C., subdivision in 0.1° C. for tests at 25° C.
" 34–42° C., " 0.1° C. " 40° C.
" 49–57° C., " 0.1° C. " 50° C.
" 95–103° C., " 0.1° C. " 100° C.

TOTAL LENGTH: 252 to 256 mm. (9.92 to 10.08 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.236 to 0.275 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 25 to 35 mm. (1.0 to 1.4 in.).
Diameter, not less than 5 mm. (0.197 in.) and not greater than that of stem.

DISTANCE TO LOWEST SPECIFIED GRADUATION FROM BOTTOM OF BULB: 135 to 150 mm. (5.3 to 5.9 in.).

DISTANCE TO HIGHEST SPECIFIED GRADUATION FROM TOP OF STEM: 20 to 35 mm. (0.8 to 1.4 in.).

CONTRACTION CHAMBER: To be of long narrow type, top to be not more than 60 mm. (2.36 in.) above bottom of bulb, mercury to stand in contraction chamber at 32° F. (0° C.).

EXPANSION CHAMBER: To permit heating the thermometer 90° F. (50° C.) above highest temperature on scale, and in all cases to permit heating to 212° F. (100° C.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures and letters clear cut and distinct. The first and each succeeding 1° F. or 0.5° C. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° F. or 1° C.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M." Viscosity test points to be numbered in full figures and in red, other graduations and figures in black. A serial number and the manufacturer's name or trade mark shall be etched on the stem.

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[1] This tube represents the average mechanically perfect tube, based on the A.S.T.M. specifications, and has been approved by the American Petroleum Institute Committee on Viscosity Standards.

SCALE ERROR: The error at any point of the scale shall not exceed 0.2° F. (0.1 C.)

STANDARDIZATION: The thermometers are to be standardized for the condition of total immersion. Correction for emergent stem shall not be applied.

CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking, "A.S.T.M., Saybolt Viscosimeter Thermometer" and the range.

II. TEMPERATURE OF TESTING

Temperature. 3. (*a*) With the Saybolt Universal viscosimeter, determinations shall be made at 100° F. (37.8° C.), 130° F. (54.4° C.) or 210° F. (98.9° C.).

(*b*) With the Saybolt Furol viscosimeter, determinations shall be made at 122° F. (50° C.).

(*c*) Viscosities shall be expressed as .... seconds, Saybolt Universal (or Saybolt Furol), being the time in seconds for the delivery of 60 cc. of oil.

(*d*) Fuel oils and other oils of similar viscosity showing a time of less than 25 seconds, Saybolt Furol, at 122° F., shall be tested on the Saybolt Universal at 122° F. Oil showing a time of less than 32 seconds, Saybolt Universal, at 122° F., shall be measured in the Saybolt Universal at 100° F. (37.8° C.). These methods of test do not apply to fuel oils having a viscosity at 100° F. of less than 32 seconds Saybolt Universal, which are not considered to be fuel oils.

III. PROCEDURE

Procedure. 4. Throughout the test the bath temperature shall not vary more than ±0.1° F. (0.06° C.) from the predetermined temperature which will maintain thermal equilibrium until the oil tube thermometer is withdrawn. Water shall be used as the bath liquid at all temperatures.[1]

Any construction of bath may be employed provided the bath temperature necessary to maintain thermal equilibrium (while the oil tube is well stirred by the oil tube thermometer) is not in excess of 100.25, 122.35, 130.50 and 212.00° F. (37.9, 50.2, 54.7 and 100.0°C.), respectively, for the standard temperatures previously mentioned. The level of the bath liquid shall not be lower than 0.5 cm. above the overflow rim of the oil tube. The heating and stirring of the water bath for the determination of viscosity at 210° F. (98.9° C.) shall be accomplished by the direct injection of steam near the bottom of the bath. The heating and stirring of the bath for other temperatures may be accomplished by any suitable means, provided the source of heat is not less than the following distances from any part of the oil tube: 2 in. (5 cm.) with an external heater, $1\frac{1}{4}$ in. (3 cm.) with an immersion heater. Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. The room temperature shall be between 68 and 86° F. (20 and 30° C.).[1] All oil introduced into the oil tube either for cleaning or for test shall first be passed through the strainer.

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[1] In ordinary routine testing it is frequently desirable to employ oil as a bath medium instead of water. This is allowable provided the temperature of the oil bath is adjusted so that the necessary condition of thermal equilibrium is maintained. It is usually necessary to maintain the oil bath at slightly higher temperatures than are necessary when water is the bath medium. Oil bath temperatures will need to be from 0.1 to 0.2° F. (0.06 to 0.11° C.) higher for tests at 100° F. (37.8° C.) and from 1.5 to 2.0° F. (0.83 to 1.11° C.) higher for tests at 210° F. (98.9° C.) than the corresponding water bath temperatures.

To make the test, heat the oil to the necessary temperature and clean out the oil tube. Pour some of the oil to be tested through the cleaned tube. Insert the cork stopper into the lower end of the air chamber at the bottom of the oil tube, sufficiently to prevent the escape of air, but not to touch the small outlet tube.

Heat the oil to be tested, outside the viscosimeter, to slightly but not more than 3° F. (1.7° C.) above the temperature at which the viscosity is to be determined, and pour it into the oil tube until it ceases to overflow into the overflow cup. By means of the oil-tube thermometer, keep the oil in the oil tube well stirred and also stir well the liquid in the bath. It is extremely important that the temperature of the bath be maintained constant during the entire time consumed in making the test. When the temperature of the bath and of the oil in the oil tube are constant and the oil in the oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60-cc. flask, Fig. 2, in position so that the stream of oil from the outlet tube will strike the neck of the flask so as to avoid foam. Snap the cork from its position, and at the same instant start the stop watch. Stir the liquid in the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60-cc. of oil is the Saybolt Universal (or Saybolt Furol) viscosity of the oil at the temperature at which the test was made.

With proper attention to details of method of procedure, duplicate results should not differ from each other by more than 1 per cent.

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[1] These limits are necessary for extreme accuracy in standardization and referee tests, but for routine purposes the use of higher temperatures up to 100° F. (37.8° C.) will not ordinarily cause an error of more than 1 per cent.

TENTATIVE METHOD OF TEST
FOR
BURNING QUALITY OF KEROSENE OILS[1]

Serial Designation: D 187 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Scope. 1. The burning test for kerosene oil is intended for the determination of the burning quality of ordinary kerosene used for illuminating purposes.

I. APPARATUS[2]

Lamp. 2. *Standard Brass Saybolt Test Lamp.* (See Fig. 1).—The lamp shall conform to the following requirements:

	INCHES	CENTIMETERS	TOLERANCES, CM.
Inside diameter of burner opening	1.21	3.08	±0.01
Top of fount to top of burner opening	0.45	1.14	0.02
Outside diameter of fount	5.50	13.97	....
Outside depth of fount	2.49	6.33	....
Bottom of fount to bottom of base	5.50	13.97	....
Filling opening			
(1) inside diameter	0.69	1.75	....
(2) distance from side of fount	0.08	0.20	....
(3) height above fount	0.33	0.83	....
Width of rim at bottom of fount	0.65	1.65	....
Thickness of metal	0.03	0.07	....

Burner. 3. *Miller No. 2 Sun Hinge Burner* (See Fig. 2) or any other burner meeting the following:

The burner shall conform to the following requirements:

	INCHES	CENTIMETERS	TOLERANCES, CM.
Thickness of metal 24 B. & S. gage	....	....	....
Height of cone from base of cone (outside)	1.20	3.05	0.05
Inside diameter of cone at base	1.81	4.60	0.02

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

[2] The equipment used in this test is selected to secure results in a reasonably short time, and it should be understood that this does not indicate any preference as to the proper type for general household use.

	INCHES	CENTIMETERS	TOLERANCES CM.
Inside diameter of cone at base of flame spreader			
(1) parallel to slot	1.43	3.64	0.02
(2) perpendicular to slot	1.43	3.62	0.02
Height of cone from base to a point 1 cm.			
(1) right of center	1.15	2.92	0.06
(2) left of center	1.15	2.92	0.06
Overall diameter of flame spreader at base	2.76	7.01	0.01
Height of collar at flame spreader base	0.31	0.79	0.07
Diameter of scallops	0.21	0.54	....
Depth of scallops	0.08	0.20	....
Center of screw to bottom of collar (outside)	0.29	0.73	....
Holes at base of spreader 28 in number,			
(1) diameter	0.09	0.24	0.01
(2) spacing, edge to edge	0.14	0.35	0.02
Space at back of flame spreader collar (without holes)	0.83	2.10	....
Space at front of flame spreader collar (without holes)	0.61	1.55	....
Width of flame spreader slot at top			
(1) center	0.39	1.00	0.03
(2) 1 cm. to left of center	0.39	1.00	0.03
(3) 1 cm. to right of center	0.39	1.00	0.03
Width of wick holder (outside)	0.96	2.44	0.01
Depth of wick holder (outside)	0.17	0.44	0.01
Length of wick holder	1.75	4.45	0.02
Width of air vent (outside)	0.34	0.87	....
Depth of air vent (outside)	0.08	0.20	....
Length of air vent	1.67	4.25	0.01
Top of wick holder to base of flame spreader slot	0.03	0.08	0.06
Base of flame spreader slot (inside) to edge of wick holder (outside)	0.23	0.59	0.07
Edge of flame spreader slot (top center) to top center edge of wick holder	0.11	0.29	0.05

Wick holder (to run parallel to flame spreader slot.)

LOWER HALF:

	INCHES	CENTIMETERS	TOLERANCES CM.
Diameter at widest point (parallel to slot)	2.22	5.64	0.02
Diameter at first constriction	2.18	5.53	0.02
Diameter at second constriction	1.96	4.97	0.02
Diameter at third constriction	1.42	3.60	0.02
Diameter at fourth constriction	1.22	3.10	0.02
Diameter at bottom	1.19	3.02	0.02
Ventilating openings, 12 in number, width,			
(1) center	0.29	0.73	0.01
(2) top and bottom	0.21	0.54	0.01
Ventilating openings, height,			
(1) center	0.24	0.61	0.01
(2) sides	0.32	0.81	0.01
Top of wick holder to top of holder support	1.01	2.57	0.03
Top of lower half of burner to outside holder support	0.62	1.57	0.02

SCREEN:	INCHES	CENTIMETERS	TOLERANCES, CM.
Diameter of screen	2.12	5.38	0.02
Length of slot in screen	1.01	2.56	0.05
Width of slot (1) narrowest point	0.20	0.52	0.02
Width of slot (2) widest point	0.30	0.75	0.02
Diameter of holes in screen	0.05	0.12	0.03
Number of holes in screen per sq. cm., 45, with a tolerance of 7			
Height of screen from base to top (over-all)	0.11	0.29	0.01
Diameter of screen at top	1.16	2.94	0.02
Diameter of screen at rim	0.10	0.26	0.01

NOTE.—The burner shall be used as received from the manufacturer provided it meets the above specifications and is free from gross imperfections of manufacture. It shall be clean and in good condition at the start of the test, but emery paper shall not be used in cleaning nor imperfections removed by means of a file or otherwise.

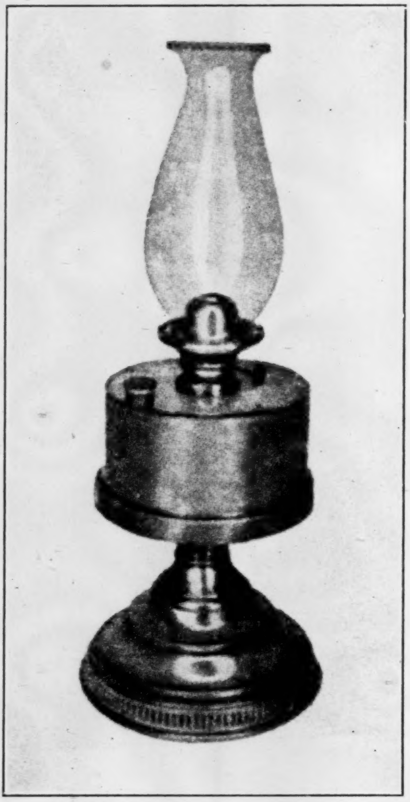

FIG 1.—Test Lamp and Chimney.

Chimney. 4. *Macbeth-Evans No. 514 Pearl Top Chimney.* (See Fig. 1.)—The chimney shall conform to the following requirements, all figures being outside measurements:

	INCHES	CENTIMETERS	TOLERANCES, CM.
Total height	8.06	20.48	0.50
Diameter of constriction			
(1) upper	1.77	4.50	0.08
(2) lower	2.27	5.77	0.07
Diameter at widest point	3.69	9.36	....
Diameter at top	2.83	7.20	0.09
Diameter at bottom	2.60	6.61	0.06
Distance from bottom to narrowest point	7.03	17.86	0.55
Distance from bottom to widest point	2.47	6.27	0.55
Distance from bottom to constriction near bottom	0.30	0.77	0.19
Thickness of glass at constriction			
(1) top	0.07	0.19	0.05
(2) bottom	0.05	0.12	0.03

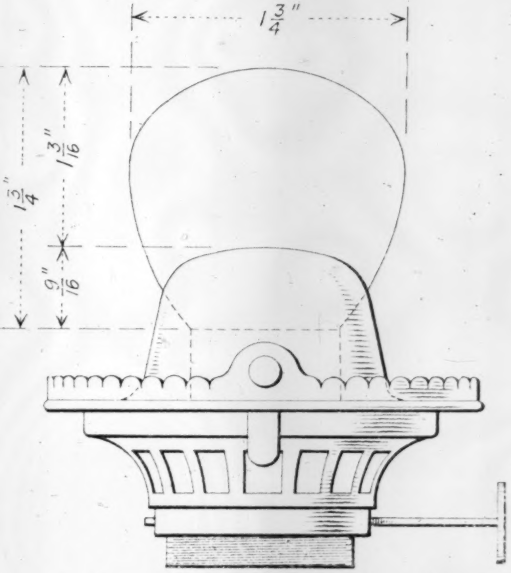

FIG. 2.—Burner.

Wick. 5. *American Wick Co.'s "B" or Similar No. 2 Wick.*—The wick shall be used as received from the manufacturer and shall not be extracted with ether or other solvent previous to use. A wick shall be rejected if it fits the wick guide too loosely or too tightly, and a new wick shall be used for each burning test.

Sight Gage. 6. A sight gage for measuring the flame height and width accurate to $\frac{1}{16}$ in. shall be used. (See Fig. 3.)

Room. 7. A special room for conducting the burning test is desirable but the lamp may be burned in any part of any adequately ventilated room reasonably free from drafts. The temperature of the room is immaterial, but is shall not vary more than 20° F. during the test.

II. PROCEDURE

Setting the Lamp.

8. The lamp shall be cleaned and 850 cc. of the oil to be tested shall be poured into the fount. The wick, wetted with the oil, shall be inserted in the burner, and the burner shall be firmly screwed into the fount. The wick shall be trimmed with the scissors so as to produce a flame, which, unless otherwise specified, shall be $1\frac{3}{4}$ in. in height measured from the top of the wick guide and $1\frac{3}{4}$ in. in width at its widest point. (See Fig. 2) The trimming should be done very carefully to produce a smooth symmetrical flame free from peaks or ears, and the lamp should be lit and the flame inspected from time to time during the course of trimming in order to determine whether the trim is satisfactory. Proper height can be obtained by turning the

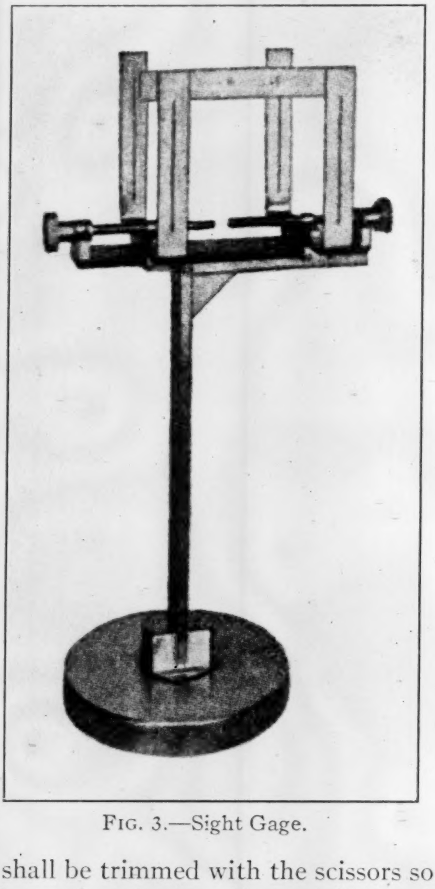

FIG. 3.—Sight Gage.

wick up or down and the proper width obtained by trimming the corners of the wick. These adjustments should be made to ± $\frac{1}{16}$ in. from the standard flame dimensions. The lamp shall be allowed to burn for one hour, and the flame then readjusted, if necessary, to the standard dimensions. At the end of the first hour the lamp shall be weighed, while burning, on a platform balance accurate to 1 g., and weighed again after exactly 60 min. further burning. The oil consumed shall be calculated in cubic centimeters per hour. The initial rate of oil consumption, thus established, shall not vary from 43 cc. per hour by more than ±2 cc. With proper attention to the flame dimensions this measurement is needed only as a check, since with a given flame size and shape the initial rate of oil consumption will always be within the limit set.

Conducting the Test.

9. The oil shall be allowed to burn continuously, without further adjustment of any kind, for the duration of the test. The lamp shall be refilled to within $\frac{1}{4}$ in. of the top of the fount, at intervals of 8 hours, without putting out the flame.

Duration of the Test.

10. Unless otherwise specified, the duration of the test shall be 24 hours of continuous burning.

Interpretation.

11. At the end of the test, the height and width of the flame and the condition of the chimney, flame, and wick, shall be noted. The final flame measurement shall be taken without refilling the lamp.

Reproducibility.

12. With care and proper attention to detail, the average oil consumption per hour should not differ in duplicate determinations by more than 2 cc. With this condition fixed, the other characteristics of the oil will be reproduced invariably, with the exception of initial mushroom formations ("ears," "niggers," "toadstools"), reproducibility of which will vary with the quality of the oil, amounting in the poorer oils to 10 per cent of the burning time.

TENTATIVE METHOD OF TEST
FOR
SULFUR IN NAPHTHAS AND ILLUMINATING OILS.[1]

Serial Designation: D 90 – 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1924.

Scope. This method is intended to be applied to illuminating oils and petroleum naphthas. It is not applicable to mixtures containing carbon bisulfide.

APPARATUS.

Absorber of chemically resistant glass, about 150-cc. capacity, containing glass beads or short pieces of glass rod in the suction side as shown.

Chimney of chemically resistant glass connected with the absorber by a rubber stopper.

Spray trap of chemically resistant glass connected with the absorber by a rubber stopper.

Small lamp of about 25-cc. capacity. This lamp may conveniently consist of a 25 to 35-cc. Erlenmeyer flask and a cork carrying a short section of glass tubing, about $\frac{1}{8}$ in. in inside diameter. The cork must be grooved along the sides so that air may enter the flask while the oil is being consumed.

Ordinary cotton wicking.

Filter pump or other means for continuous suction and rubber tubing to connect with spray trap.

SOLUTIONS REQUIRED.

Hydrochloric acid.—Solution containing 2.275 g. HCl per liter and carefully checked for accuracy.

Sodium carbonate.—Solution containing 3.306 g. Na_2CO_3 per liter. Exactly 10.0 cc. should be required to neutralize 10.0 cc. of the hydrochloric acid solution.

Methyl orange.—Solution in distilled water, containing 0.004 g. methyl orange per liter.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

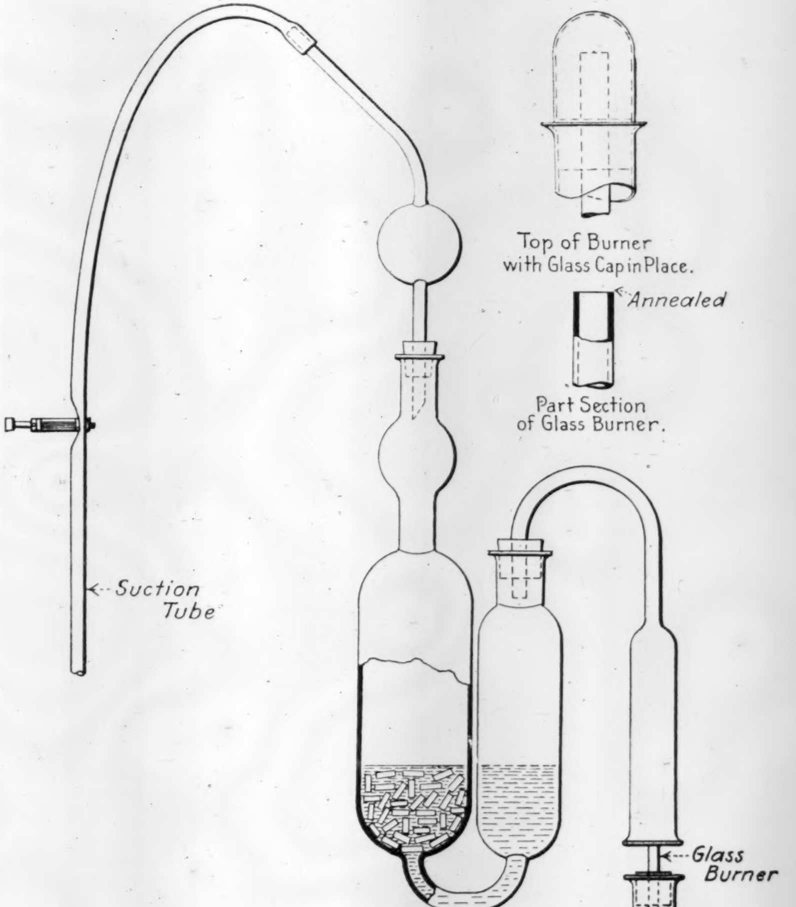
Top of Burner
with Glass Cap in Place.
Annealed
Part Section
of Glass Burner.
Suction
Tube
Glass
Burner

FIG. 1.—Apparatus for Determination of Sulfur in Oils.

PROCEDURE.

Pass two strands of new cotton wicking about 4.5 in. long through the $\frac{1}{8}$-in. diameter wick tube so that they are not twisted but parallel in the wick tube. Trim the wick with very sharp scissors. Pour into the clean dry lamp about 20 cc. of the oil to be tested, insert the wick and cork and weigh the assembly with an accuracy of 0.001 g. It is advisable to make a blank determination at the same time and under the same conditions by burning sulfur-free alcohol in a similar lamp.

Rinse out the absorber containing the glass beads thoroughly with distilled water and add exactly 10.0 cc. of the standard sodium carbonate solution from an accurately calibrated burette, allowing the burette to drain for three minutes before taking the reading. Rinse the chimney and the spray trap with distilled water, dry the chimney and connect both to the absorber as shown in Fig. 1. Set up the apparatus for the blank determination in exactly the same manner and using exactly 10.0 cc. of the sodium carbonate solution. Apply gentle suction to both absorbers, light both the weighed oil lamp and alcohol lamp and then place in position under the chimneys so that the tops of the wick tubes extend into the chimneys not more than $\frac{1}{16}$ in. Adjust the wick height and the suction so that the flame is steady, free from smoke and approximately $\frac{1}{4}$ in. high. This requires that the wick be flush with the top of the wick tube for naphthas and a little higher for illuminating oils. The room must be free from drafts. The suction on the blank should be so adjusted that air is drawn through both determinations at the same rate. Continue burning for about two hours, or less if the sulfur content of the oil is high. During this time the oil should be consumed at the rate of about 1 g. per hour.

Extinguish the flames and stop the suction on both absorbers. Weigh the oil lamp immediately and calculate by difference the weight of oil consumed. Working with the blank first, disconnect the spray trap and chimney and wash them thoroughly with the methyl orange solution, using a wash bottle with a very fine jet and collecting the washings in the absorber. The amount of solution required for washing should not exceed 35 cc. Carefully titrate the very faintly yellowish solution in the absorber with standard HCl, added to the suction side of the absorber from an accurately calibrated burette. During this titration, the contents of the absorber should be agitated carefully, either by blowing through a rubber tube held between the operator's lips and connected at the other end with the chimney side of the absorber or else by the use of a suitable rubber syringe bulb.

As the end point is approached, draw the liquid back into the chimney side between each addition of acid and then blow it into the suction side, agitating as before. As soon as the first permanent pink color appears, the end point has been reached. Read and record the volume of HCl solution used.

Rinse the chimney and spray trap used in the actual determination into the absorber to which they were connected, exactly as prescribed for the blank. If the methyl orange solution in the absorber has a pink color, too much oil has been burned and the determination must be repeated, burning for a shorter time. Titrate just as in the blank, making sure that the absorber is cold. Read and record the volume of HCl solution required.

Calculate the sulfur content of the oil by substituting the proper values in the following formula:

$$\text{Percentage of Sulfur} = \frac{(\text{HCl for blank, cc.} - \text{HCl for sample, cc.}) \times 0.1}{\text{grams of oil burned}}$$

If a blank is not run, the formula is:

$$\text{Percentage of Sulfur} = \frac{(\text{Na}_2\text{CO}_3\text{, cc.} - \text{HCl, cc.}) \times 0.1}{\text{grams of oil burned}}$$

These formulas are correct only for the standard solutions specified, 1 cc. of each being equivalent to 0.001 g. of sulfur. The use of solutions of any other strength, such as N/10, involves more complicated calculation and is not advisable.

TENTATIVE METHOD OF TEST
FOR
FREE ACID IN LUBRICANTS[1]

Serial Designation: D 188 - 24 T

Issued, 1924.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

FREE ACID.

Free Acid. 1. Accurately weigh 10 g. of the oil into a flask, add 50 cc. of 95-per-cent alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein as an indicator, agitating thoroughly after each addition of alkali.

Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 g. of fat or oil).

1 cc. of tenth-normal alkali = 0.0282 g. of oleic acid. Alkali, 1 cc. of which is equivalent to 0.00996 g. of KOH, and 1 cc. of which is equivalent to 0.5 per cent of oleic acid, may be used.

Follow the same method for mineral oils excepting the alcohol which should consist of equal proportions of distilled water and 95-per-cent alcohol.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

TENTATIVE METHOD OF TEST
FOR
CARBON RESIDUE OF LUBRICANTS[1]

Serial Designation: D 189 - 24 T

ISSUED, 1924.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

CARBON RESIDUE[2]

(CONRADSON METHOD)

Apparatus.

1. The apparatus (see Fig. 1) consists of:

(*a*) Porcelain crucible, wide form, glazed throughout, 25 to 26-cc. capacity, 46 mm. in diameter.

(*b*) Skidmore iron crucible, 45-cc. ($1\frac{1}{2}$-oz.) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

(*c*) Wrought-iron crucible with cover, about 180 cc. capacity, 80 mm. diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought-iron crucible.

(*d*) Triangle, pipe stem covered, projection on side so as to allow flame to reach the crucible on all sides.

(*e*) Sheet iron or asbestos hood provided with a chimney about 2 to $2\frac{1}{2}$ in. high, $2\frac{1}{8}$ to $2\frac{1}{4}$ in. in diameter to distribute the heat uniformly during the process.

(*f*) Asbestos or hollow sheet iron block, 6 to 7 in. square, $1\frac{1}{4}$ to $1\frac{1}{2}$ in. high, provided with opening in center $3\frac{1}{4}$ in. in diameter at the bottom, and $3\frac{1}{2}$ in. in diameter at the top.

Procedure.

2. The test shall be conducted as follows:

Ten grams of the oil to be tested are weighed in the porcelain crucible, which is placed in the Skidmore crucible and these two crucibles set in the larger iron crucible, being careful to have the Skidmore crucible set in the center of the iron crucible, covers being applied to the Skidmore and iron crucibles.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Van. H. Manning, Secretary of Committee D-2 on Petroleum Products and Lubricants, Pan-American Petroleum and Transport Co., 120 Broadway, New York City.

[2] This method is a modification by P. H. Conradson of his original method and apparatus for Carbon Test and Ash Residue in Petroleum Lubricating Oils. See *Proceedings*, Eighth International Congress of Applied Chemistry, New York, September, 1912, Vol. 1, p. 131; also reprint in the *Journal of Industrial and Engineering Chemistry*, Vol. 4, No. 11, November, 1912.

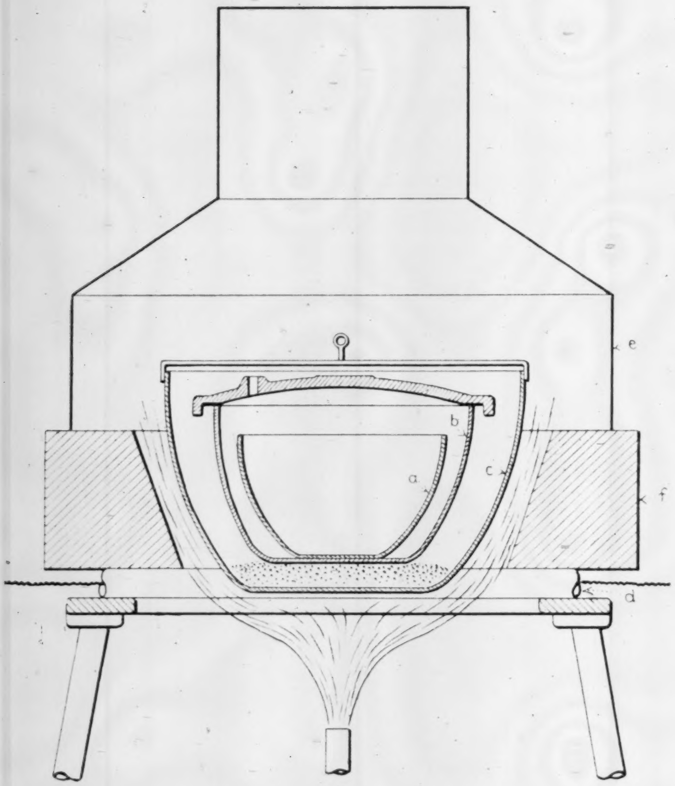

Fig. 1.—Apparatus for Determining Carbon Residue.

Place on triangle and suitable stand with asbestos block and cover with sheet iron or asbestos hood in order to distribute the heat uniformly during the process.

Heat from a Bunsen burner or other burner is applied with a high flame surrounding the large crucible, as shown in

Fig. 1, until vapors from the oil start to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over 2 in. above the sheet iron hood. After the vapor ceases to come off the heat is increased as at the start and kept so for five minutes, making the lower part of large crucible red hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a desiccator and weighed.

The entire process should require about one-half hour to complete when heat is properly regulated. The time will depend somewhat upon the kind of oil tested, as a very thin, rather low-flash-point oil will not take as long as a heavy, thick, high-flash-point oil.

TENTATIVE SPECIFICATIONS
FOR
BROKEN STONE FOR WATERBOUND BASE[1]

Serial Designation: D 190 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered.

1. These specifications cover the quality and grading of broken stone and stone screenings for use in a waterbound broken stone base course which is to be covered with any type of surface.

General Characteristics.

2. The broken stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces.

3. Stone for screenings shall be of suitable binding quality.

Physical Properties.

4. The stone shall conform to the following requirement:

Percentage of wear.................................not more than 7.0

$1\frac{1}{4}$ to $2\frac{1}{2}$ in. or $2\frac{1}{2}$ to $3\frac{1}{2}$ in. Size.

5. The course aggregate shall be of either (1) the $1\frac{1}{4}$ to $2\frac{1}{2}$-in. size or (2) the $2\frac{1}{2}$ to $3\frac{1}{2}$-in. size, and shall be well graded between the limits specified. When tested by means of laboratory screens, it shall conform to one of the following requirements:

(*a*)	Passing $1\frac{1}{4}$-in. screen........................	0 to 15 per cent
	Passing $2\frac{1}{2}$-in. screen........................	95 to 100 "
(*b*)	Passing $2\frac{1}{2}$-in. screen........................	0 to 15 per cent
	Passing $3\frac{1}{2}$-in. screen........................	95 to 100 "

NOTE.—Either of the above sizes or a combination thereof may be specified as desired.

0 to $\frac{1}{4}$-in. or 0 to $\frac{3}{4}$-in. Size.

6. The screenings shall be of either (1) the 0 to $\frac{1}{4}$-in. size, or (2) the 0 to $\frac{3}{4}$-in. size, well-graded from coarse to fine and free from dirt or other foreign material. When tested by means of laboratory screens they shall conform to one of the following requirements:

(*a*)	Passing $\frac{1}{4}$-in. screen........................	85 to 100 per cent
(*b*)	Passing $\frac{1}{4}$-in. screen........................	40 to 80 per cent
	Passing $\frac{3}{4}$-in. screen........................	95 to 100 "

NOTE.—Either of the above alternate sizes may be specified as desired.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

7. (*a*) The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material (Serial Designation: D 2) of the American Society for Testing Materials.[1] **Methods of Testing.**

(*b*) Determinations of size shall be made in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1]

8. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1] **Methods of Sampling.**

NOTE.—The test values for quality of stone incorporated in these specifications are suggested as the lowest safe requirements. It is not expected, however, that the limits for size and quality will be applicable to all localities and conditions.

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN STONE FOR WATERBOUND MACADAM SURFACE COURSE[1]

Serial Designation: D 191 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover the quality and grading of broken stone and broken stone screenings for use in waterbound macadam surface course.

General Characteristics. 2. The broken stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces.

3. Stone for screenings shall be of suitable binding quality.

Physical Properties. 4. The stone shall conform to the following requirements:

Percentage of wear	not more than 6
Toughness	not less than 6

$1\frac{1}{4}$ to $2\frac{1}{2}$ in. or $2\frac{1}{2}$ to $3\frac{1}{2}$-in. Size. 5. The coarse stone shall be of (1) the $1\frac{1}{4}$ to $2\frac{1}{2}$-in. size or (2) the $2\frac{1}{2}$ to $3\frac{1}{2}$-in size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

(*a*)	Passing $1\frac{1}{4}$-in. screen	0 to 15 per cent
	Passing $2\frac{1}{2}$-in. screen	95 to 100 "
(*b*)	Passing $2\frac{1}{2}$-in. screen	0 to 15 per cent
	Passing $3\frac{1}{2}$-in. screen	95 to 100 "

NOTE.—Either of the above sizes or a combination thereof may be specified as desired.

0 to $\frac{1}{4}$-in. or 0 to $\frac{3}{4}$-in. Size. 6. The screenings shall be of either (1) the 0 to $\frac{1}{4}$-in. size, or (2) the 0 to $\frac{3}{4}$-in. size, well graded from coarse to fine and free from dirt or other foreign material. When tested by means of laboratory screens it shall conform to one of the following requirements:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

(*a*)	Passing ¼-in. screen	85 to 100 per cent
(*b*)	Passing ¼-in. screen	40 to 80 per cent
	Passing ¾-in. screen	95 to 100 "

NOTE.—Either of the above alternate sizes may be specified as desired.

Methods of Testing.

7. (*a*) The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material (Serial Designation: D 2) of the American Society for Testing Materials.[1]

(*b*) The toughness shall be determined in accordance with the Standard Method of Test for Toughness of Rock (Serial Designation: D 3) of the American Society for Testing Materials.[1]

(*c*) Determinations of size shall be made in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1]

Methods of Sampling.

8. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

NOTE.—The test values for quality of stone incorporated in these specifications are suggested as the lowest safe requirements. It is not expected, however, that the limits for size and quality will be applicable to all localities and conditions.

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN STONE FOR BITUMINOUS MACADAM[1]

Serial Designation: D 192 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover the quality and grading of broken stone for use in a bituminous macadam surface course or bituminous macadam base.

General Characteristics. 2. The broken stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, and free from stone coated with dirt or other objectionable matter.

Physical Properties. 3. The stone shall conform to the following requirements:

Percentage of wear	not more than 6
Toughness	not less than 6

$1\frac{1}{4}$ to $2\frac{1}{2}$-in. or $2\frac{1}{2}$ to $3\frac{1}{2}$-in. Size. 4. The coarse stone shall be either (1) the $1\frac{1}{4}$ to $2\frac{1}{2}$-in. size or (2) the $2\frac{1}{2}$ to $3\frac{1}{2}$-in. size and shall be well graded between the limits specified. When tested by means of laboratory screens it shall conform to one of the following requirements.

(*a*)	Passing $1\frac{1}{4}$-in. screen	0 to 15 per cent
	Passing $2\frac{1}{2}$-in. screen	95 to 100 "
(*b*)	Passing $2\frac{1}{2}$-in. screen	0 to 15 per cent
	Passing $3\frac{1}{2}$-in. screen	95 to 100 "

$\frac{3}{4}$ to $1\frac{1}{4}$-in. Size. 5. The stone for filling the surface voids in the coarse aggregate shall be the $\frac{3}{4}$ to $1\frac{1}{4}$-in. size, and when tested by means of laboratory screens shall conform to the following requirements:

Passing $\frac{3}{4}$-in. screen	0 to 15 per cent
Passing 1-in. screen	25 to 75 "
Passing $1\frac{1}{4}$-in. screen	95 to 100 "

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

¼ to ¾-in. Size.

6. Stone chips for use in the seal coat shall be of the ¼ to ¾-in. size, and when tested by means of laboratory screens shall conform to the following requirements:

Passing ¼-in. screen	0 to	15 per cent
Passing ½-in. screen	25 to	75 "
Passing ¾-in. screen	95 to	100 "

Methods of Testing.

7. (*a*) The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material (Serial Designation: D 2) of the American Society for Testing Materials.[1]

(*b*) The toughness shall be determined in accordance with the Standard Method of Test for Toughness of Rock (Serial Designation: D 3) of the American Society for Testing Materials.[1]

(*c*) Determinations of size shall be made in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1]

Methods of Sampling.

8. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

NOTE.—The test values for quality of stone incorporated in these specifications are suggested as the lowest safe requirements. It is not expected, however, that the limits for size and quality will be applicable to all localities and conditions.

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN STONE FOR BITUMINOUS CONCRETE BASE[1]

Serial Designation: D 193 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover the quality and grading of broken stone to be used in the construction of a closed mix and an open mix bituminous concrete base.

General Characteristics. 2. The broken stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces.

Physical Properties. 3. The stone shall conform to the following requirements:

Percentage of wear	not more than 6
Toughness	not less than 6

Coarse Aggregate for Open Mix Bituminous Concrete Base $1\frac{1}{4}$ to $2\frac{1}{2}$-in. Size 4. The coarse aggregate for open mix bituminous concrete base shall consist of the $1\frac{1}{4}$ to $2\frac{1}{2}$-in. size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

Passing $1\frac{1}{4}$-in. screen	0 to 15 per cent
Passing $2\frac{1}{2}$-in. screen	95 to 100 "

Coarse Aggregate for Closed Mix Bituminous Concrete Base $\frac{1}{4}$ to $2\frac{1}{2}$ in. Size. 5. The coarse aggregate for closed mix bituminous concrete base shall consist of the $\frac{1}{4}$ to $2\frac{1}{2}$-in. size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

Passing $\frac{1}{4}$-in. screen	0 to 5 per cent
Passing $1\frac{1}{4}$-in. screen	25 to 75 "
Passing $2\frac{1}{2}$-in. screen	95 to 100 "

Methods of Testing. 6. (*a*) The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

(Serial Designation: D 2) of the American Society for Testing Materials.[1]

(*b*) The toughness shall be determined in accordance with the Standard Method of Test for Toughness of Rock (Serial Designation: D 3) of the American Society for Testing Materials.[1]

(*c*) Determinations of size shall be made in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1]

Methods of Sampling.

7. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN STONE FOR BITUMINOUS CONCRETE SURFACE[1]

Serial Designation: D 194 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered.

1. These specifications cover the quality and grading of broken stone to be used in the construction of fine-graded bituminous concrete pavements (Modified Topeka, or stone-filled sheet asphalt) and coarse-graded bituminous concrete, including asphaltic concrete binder.

General Characteristics.

2. The broken stone shall consist of clean tough durable fragments free from an excess of flat, elongated, soft, or disintegrated pieces, and free from stone coated with dirt or other objectionable matter.

Physical Properties.

3. The stone shall conform to the following requirements:

Percentage of wear	not more than 6
Toughness	not less than 6

Stone Chips for Seal Coat $\frac{1}{4}$ to $\frac{1}{2}$-in. Size.

4. Stone chips shall be of the $\frac{1}{4}$ to $\frac{1}{2}$-in. size. When tested by means of laboratory screens they shall conform to the following requirements:

Passing $\frac{1}{4}$-in. screen	0 to 15 per cent
Passing $\frac{1}{2}$-in. screen	95 to 100 "

Coarse Aggregate for Fine-graded Bituminous Concrete Mixture $\frac{1}{4}$ to $\frac{3}{4}$-in. Size.

5. The coarse aggregate for fine-grade bituminous concrete shall be of the $\frac{1}{4}$ to $\frac{3}{4}$-in. size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

Passing $\frac{1}{4}$-in. screen	0 to 15 per cent
Passing $\frac{1}{2}$-in. screen	25 to 75 "
Passing $\frac{3}{4}$-in. screen	95 to 100 "

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

Coarse Aggregate for Coarse-graded Bituminous Concrete Mixture ¼ to 1¼-in. Size.

6. The coarse aggregate for coarse-graded bituminous concrete shall consist of the ¼ to 1¼-in. size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

Passing ¼-in. screen	0 to 10	per cent
Passing ¾-in. screen	25 to 75	"
Passing 1¼-in. screen	95 to 100	"

Methods of Testing.

7. (*a*) The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material (Serial Designation: D 2) of the American Society for Testing Materials.[1]

(*b*) The toughness shall be determined in accordance with the Standard Method of Test for Toughness of Rock (Serial Designation: D 3) of the American Society for Testing Materials.[1]

(*c*) Determinations of size shall be made in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1]

Methods of Sampling.

8. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN SLAG FOR BITUMINOUS MACADAM BASE[1]

Serial Designation: D 195 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover ¾ to 1¼-in., 1¼ to 2½-in., and 2½ to 3½-in. size broken slag to be used in the construction of a bituminous macadam base in which the bituminous material is applied by the penetration method and which is to be covered with any type of surface course.

The 2½ to 3½-in. size is intended for use as a first course, which will be penetrated with bituminous material, when a base of over 3½ in. is desired.

The 1¼ to 2½-in. size is intended for use as a second course which is to be penetrated with bituminous material.

The ¾ to 1¼-in. size is intended to fill the surface voids when a sheet asphalt or a fine-graded bituminous concrete is to be placed directly upon it. This material can be omitted when a coarse-graded bituminous concrete or a binder course is to be laid directly upon the base.

General Characteristics. 2. The broken slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Weight. 3. The weight per cubic foot of each size specified shall be not less than 65 lb.

2½ to 3½-in. and 1¼ to 2½-in. Size. 4. The coarse slag when tested by means of laboratory screens shall conform to the following requirements:

(*a*)	Passing 3½-in. screen	not less than 95 per cent
	Total passing 2½-in. screen	not more than 15 "
(*b*)	Passing 2½-in. screen	not less than 95 per cent
	Total passing 1¼-in. screen	not more than 15 "

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

¾ to 1¼-in. Size.

5. The intermediate size slag when tested by means of laboratory screens shall conform to the following requirements:

Passing 1¼-in. screen	not less than 95 per cent
Passing 1-in. screen	25 to 75 "
Passing ¾-in. screen	not more than 15 "

Methods of Testing.

6. *Weight per Cubic Foot.*—The weight per cubic foot shall be determined in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[1]

Sampling.

7. The method of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

NOTE.—The test values for quality of slag incorporated in these specifications are suggested as the lowest safe requirements. It is not expected, however, that the limits for size and quality will be applicable to all conditions.

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN SLAG FOR BITUMINOUS CONCRETE BASE[1]

Serial Designation: D 196 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered. 1. These specifications cover ¼ to 1¼-in. and ¼ to 2½-in. size broken slag, either of which is to be used in the construction of a bituminous concrete base prepared by the mixing method and upon which may be placed any type of surface course.

General Characteristics. 2. The broken slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Weight. 3. The weight per cubic foot of each size specified shall be not less than 70 lb.

¼ to 1¼-in. or ¼ to 2½-in. Size. 4. The slag when tested by means of laboratory screens shall conform to one of the following requirements:

(*a*)	Passing 1¼-in. screen	not less than 95 per cent
	Passing ¾-in. screen	25 to 75 "
	Passing ¼-in. screen	not more than 5 "
(*b*)	Passing 2½-in. screen	not less than 95 per cent
	Passing 1¼-in. screen	25 to 75 "
	Passing ¼-in. screen	not more than 5 "

NOTE.—One of the above alternate sizes for broken slag should be specified to best suit the local and service conditions.

Methods of Testing. 5. *Weight per Cubic Foot.*—The weight per cubic foot shall be determined in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[2]

Methods of Sampling. 6. The methods of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN SLAG FOR BITUMINOUS MACADAM WEARING COURSE[1]

Serial Designation: D 159 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Material Covered.

1. These specifications cover $\frac{3}{4}$ to $\frac{1}{4}$-in., $1\frac{1}{4}$ to $\frac{3}{4}$-in., and $2\frac{1}{2}$ to $1\frac{1}{4}$-in. or $3\frac{1}{2}$ to $2\frac{1}{2}$-in. size slag to be used in the construction of a bituminous macadam wearing course in which the bituminous material is applied by the penetration method. The maximum size of $3\frac{1}{2}$ in. specified for the wearing course is on the basis of a course $2\frac{1}{2}$ to $3\frac{1}{2}$ in. in thickness after consolidation. The $1\frac{1}{4}$ to $\frac{3}{4}$-in. size should be used to fill the surface voids after the first application of bituminous material, and the $\frac{3}{4}$ to $\frac{1}{4}$-in. size after the application of the seal coat.

General Characteristics of Slag.

2. The broken slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Weight.

3. The weight per cubic foot of each size specified shall be not less than 70 lb.

3/4 to 1/4-in. Size.

4. The $\frac{3}{4}$ to $\frac{1}{4}$-in. size is that portion of the product of the crusher, which, when tested by means of laboratory screens, shall meet the following requirements:

Passing $\frac{3}{4}$-in. screen	not less than 95 per cent
Passing $\frac{1}{2}$-in. screen	25 to 75 "
Passing $\frac{1}{4}$-in. screen	not more than 15 "

1¼ to 3/4-in. Size.

5. The $1\frac{1}{4}$ to $\frac{3}{4}$-in. size is that portion of the product of the crusher, which, when tested by means of laboratory screens, shall meet the following requirements.

Passing $1\frac{1}{4}$-in. screen	not less than 95 per cent
Passing 1-in. screen	25 to 75 "
Passing $\frac{3}{4}$-in. screen	not more than 15 "

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

2½ to 1¾-in. Size. 6. The 2½ to 1¼-in. and 3½ to 2½-in. sizes are that portion of the product of the crusher, which, when tested by means of laboratory screens, shall conform to one of the following requirements:

Passing 2½-in. screen	not less than 95 per cent
Total passing 1¼-in. screen	not more than 15 "
Passing 3½-in. screen	not less than 95 per cent
Total passing 2½-in. screen	not more than 15 "

NOTE.—One of the above alternate sizes for coarse slag should be specified to best suit the local and service conditions.

Methods of Testing. 7. *Weight per Cubic Foot.*—The weight per cubic foot shall be determined in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[1]

Sampling. 8. The method of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN SLAG FOR BITUMINOUS CONCRETE (COARSE-GRADED AGGREGATE TYPE)[1]

Serial Designation: D 160 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Material Covered.

1. These specifications cover ¾ to ¼-in. and 1¼ to ¼-in. size slag to be used in the construction of a coarse-graded bituminous concrete wearing course constructed by the mixing method. The ¾ to ¼-in. size should be used after the application of the seal coat when a seal coat is used.

General Characteristics of Slag.

2. The broken slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Weight.

3. The weight per cubic foot of each size specified shall be not less than 70 lb.

¾ to ¼-in. Size.

4. The ¾ to ¼-in. size is that portion of the product of the crusher, which, when tested by means of laboratory screens, shall meet the following requirements:

Passing ¾-in. screen	not less than 95 per cent
Passing ½-in. screen	25 to 75 "
Passing ¼-in. screen	not more than 15 "

1¼ to ¼-in. Size.

5. The 1¼ to ¼-in. size is that portion of the product of the crusher, which, when tested by means of laboratory screens, shall meet the following requirements:

Passing 1¼-in. screen	95 to 100 per cent
Passing ¾-in. screen	25 to 75 "
Passing ¼-in. screen	not more than 5 "

Methods of Testing.

6. *Weight per Cubic Foot.*—The weight per cubic foot shall be determined in accordance with the Standard Method of Test for

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[1]

Sampling. 7. The method of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
BROKEN SLAG FOR BITUMINOUS CONCRETE (FINE-GRADED AGGREGATE TYPE)[1]

Serial Designation: D 161 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Material Covered. 1. These specifications cover slag aggregate to be used in the construction of a bituminous concrete wearing surface constructed by the mixing method.

General Characteristics of Slag. 2. The broken slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Weight. 3. The weight per cubic foot shall be not less than 70 lb.

Slag Aggregate 0 to $\frac{1}{2}$-in. Size. 4. The slag aggregate is that portion of the product of the crusher, which, when tested by means of laboratory screens, shall conform to the following requirements:

Passing $\frac{1}{2}$-in. screen	95 to 100 per cent
Passing $\frac{1}{4}$-in. screen	0 to 75 "

Methods of Testing. 5. *Weight per Cubic Foot.*—The weight per cubic foot shall be determined in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[2]

Sampling. 6. The method of sampling shall conform to the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT 85 TO 100 PENETRATION, FOR USE IN ASPHALT MACADAM PAVEMENTS.[1]

Serial Designation: D 102 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1922, 1923, 1924.

Properties.

1. The asphalt cement shall be homogeneous and free from water. It shall conform to the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec. . . . . . . 85 to 100
(*b*) Flash point (open cup) . . . . not less than 175° C. (347° F.)
(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr. . . . . not more than 2 per cent
Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating. . not less than 60 per cent
(*d*) Ductility at 25° C. (77° F.) . . . . not less than 30 cm.
(*e*) Proportion of bitumen soluble in carbon tetrachloride . . . . not less than 99 per cent

NOTE.—When less than 99 per cent of the asphalt cement is soluble in carbon tetrachloride, the percentage of bitumen (solubility in carbon disulfide) shall be reported.

Methods of Testing.

2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92);[2]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 22 T);[3]

(*e*) *Proportion of Bitumen Soluble in Carbon Tetrachloride:* Tentative Method of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride (Serial Designation: D 165 - 23 T).[4]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 754 (1923).

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 100 TO 120 PENETRATION, FOR USE IN ASPHALT MACADAM PAVEMENTS.[1]

Serial Designation: D 103 - 24 T.

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1922, 1923, 1924.

Properties.

1. The asphalt cement shall be homogeneous and free from water. It shall conform to the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec.....100 to 120

(*b*) Flash point (open-cup)........not less than 175° C. (347° F.)

(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr...not more than 2 per cent

Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating..not less than 60 per cent

(*d*) Ductility at 25° C. (77° F.)............not less than 30 cm.

(*e*) Proportion of bitumen soluble in carbon tetrachloride...................................not less than 99 per cent

NOTE.—When less than 99 per cent of the asphalt cement is soluble in carbon tetrachloride, the percentage of bitumen (solubility in carbon disulfide shall be reported.

Methods of Testing.

2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92);[2]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 22 T);[3]

(*e*) *Proportion of Bitumen Soluble in Carbon Tetrachloride:* Tentative Method of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride (Serial Designation: D 165 - 23 T).[4]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1924 Book of A.S.T.M. Standards.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 754 (1923).

TENTATIVE METHOD OF MECHANICAL ANALYSIS OF SUBGRADE SOILS.[1]

Serial Designation: D 137 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1923, 1924.

Scope.

1. This method covers the determination of the amount of sand, silt, clay and suspension clay[2] in subgrade soils.

Treatment of Sample.

2. The sample as received shall be dried in an oven at a temperature not to exceed 100° C. (212° F.) and shall then be broken up in a mortar by means of a rubber-covered pestle, care being taken not to break any fragments of rock or sand. The sample shall then be passed through a ¼-in. screen and the material passing this screen further pulverized by rolling out in a thin layer on a rubber pad, using a rubber-covered roller.

Apparatus.

3. The apparatus shall consist of a wide-mouthed cylindrical glass jar of at least 10 liters capacity; a soil centrifuge with a four or eight-tube head of such diameter that a speed of 1500 r.p.m. will exert a centrifugal force approximately 500 times the force of gravity; four centrifuge tubes of 100-cc. capacity; and a chemical balance sensitive to 0.001 g.

Procedure when Determination of Suspension Clay is Required.

4. By the method of quartering, a sample weighing approximately 25 g., prepared as specified in Section 2, shall be placed in a beaker with approximately 500 cc. of distilled water. This mixture shall be gradually brought up to the boiling point during a period of one hour and then be allowed to simmer for an additional hour. After standing until cool, the material in the beaker shall be thoroughly brushed and dispersed with a stiff brush for two or three minutes and then allowed to stand for eight minutes. The super-

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] The determination of the percentage of suspension clay by this method will include any water-soluble material present which may be determined separately if desired.

natant liquid shall then be decanted to a depth of 8 cm. from the surface of the liquid into a vessel having a capacity of about 10 liters. About 500 cc. of ammoniated water (concentration 1 : 500) shall be added to the material remaining in the beaker and the brushing repeated as before. After again standing for eight minutes, the supernatant liquid shall be decanted into the large vessel. This process shall be repeated until the supernatant liquid becomes clear after eight minutes sedimentation. The sand and silt have now been separated from the clay and suspension clay, which are contained in the large vessel. The material in the beaker shall then be transferred to an evaporating dish, dried to constant weight at a temperature not to exceed 100° C. (212° F.), cooled, and a mechanical analysis made, using 20-mesh, 60-mesh, 100-mesh and 200-mesh sieves. Material retained on each sieve shall be recorded as percentage of the original sample, and that which passes the 200-mesh sieve shall be recorded as the percentage of silt in the original sample.

The volume of liquid in the large vessel shall now be brought up to at least 10 liters by the addition of ammoniated water, and the vessel thoroughly shaken until all material is in suspension. Seventy cubic centimeters of the liquid shall then be siphoned from this vessel at a depth of about one-half the total depth of the liquid into each of four centrifuge tubes. The tubes shall then be mounted in the centrifuge and run for 30 minutes at a speed which, for the diameter of the head used, will exert a centrifugal force approximately 500 times the force of gravity. The material which has been thrown out of the liquid by centrifuging shall be classified as clay and that which remains in suspension as suspension clay. The solution containing the suspension clay shall then be decanted, evaporated to dryness, and the weight of the suspension clay determined. The clay remaining in the tube shall also be dried and weighed.

The weight of suspension clay is found from the liquid in four tubes, or 280 cc.; consequently this weight must be multiplied by the factor obtained by dividing the total volume used by 280 cc. in order to obtain the total suspension clay in the original sample. The weight of clay is determined from the clay in one tube, or 70 cc.; therefore the total volume divided by 70 cc. gives the factor by which this weight should be multiplied to give the total clay in the original sample. The total weights of clay and suspension clay thus obtained are converted into percentages of the original 25-g. sample. The determination of the percentage of suspension clay by this method includes any water-soluble material present which may be determined separately if desired.

Procedure when Determination of Suspension Clay is not Required.

5. In case it is not considered necessary to make a determination of the percentage of suspension clay, the following procedure for determination of total clay (clay plus suspension clay) may be followed:

An aliquot portion of the total volume of water used in washing the sample shall be taken and evaporated to dryness and the weight of clay plus suspension clay obtained, which shall be expressed as the percentage of total clay in the original 25-g. sample.

TENTATIVE METHOD OF FLOAT TEST
FOR
BITUMINOUS MATERIALS[1]

Serial Designation: D 139 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1923, 1924.

I. APPARATUS.

Float. 1. The float (Fig. 1) shall be made of aluminum or aluminum alloy and shall be in accordance with the following requirements:

	MINIMUM.	NORMAL.	MAXIMUM.
Weight of float, g.	37.70	37.90	38.10
Total height of float, mm.	34.0	35.0	36.0
Height of rim above lower side of shoulder, mm.	26.5	27.0	27.5
Thickness of shoulder, mm.	1.3	1.4	1.5
Diameter of opening, mm.	11.0	11.1	11.2
Height of rim above water with load of 5.5 g., mm.	7.0	8.5	10.0

Collar. 2. The collar (Fig. 1) shall be made of brass and shall be in accordance with the following requirements:

	MINIMUM.	NORMAL.	MAXIMUM.
Weight of collar, g.	9.60	9.80	10.00
Over-all height of collar, mm.	22.3	22.5	22.7
Inside diameter at bottom, mm.	12.72	12.82	12.92
Inside diameter at top, mm.	9.65	9.70	9.75

The top of the collar shall screw up tightly against the lower side of the shoulder.

Thermometer. 3. The thermometer shall conform to the following requirements. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 0 to 80° C. or 30 to 180° F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −2 to +80° C. in 0.2° C. or +30 to +180° F. in 0.5° F.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, 9 to 14 mm. (0.35 to 0.55 in.).
Diameter, 4.5 to 5.5 mm. (0.18 to 0.22 in.).

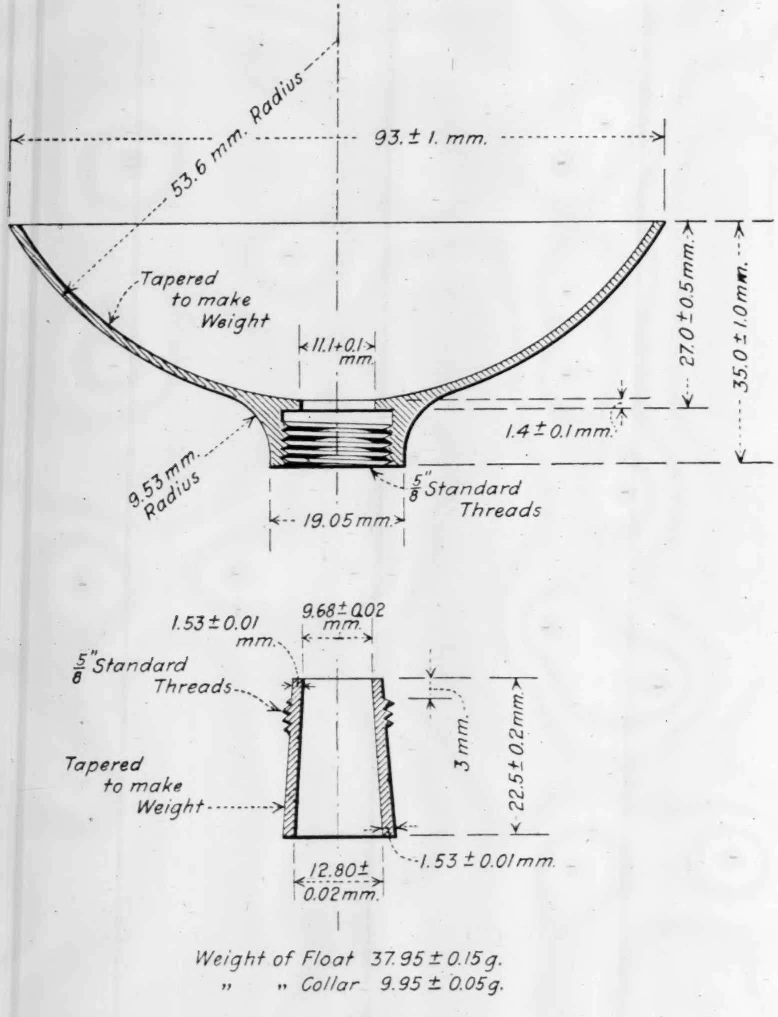
53.6 mm. Radius
93. ± 1. mm.
Tapered to make Weight
11.1+0.1 mm.
27.0 ± 0.5 mm.
35.0 ± 1.0 mm.
1.4 ± 0.1 mm.
9.53 mm. Radius
5/8" Standard Threads
19.05 mm.
1.53 ± 0.01 mm.
9.68 ± 0.02 mm.
5/8" Standard Threads
3 mm.
22.5 ± 0.2 mm.
Tapered to make Weight
12.80 ± 0.02 mm.
1.53 ± 0.01 mm.
Weight of Float 37.95 ± 0.15 g.
" " Collar 9.95 ± 0.05 g.

FIG. 1.—Float and Collar

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 75 to 90 mm. (2.95 to 3.54 in.).

DISTANCE TO 80° C. OR 176° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

EXPANSION CHAMBER: To permit heating the thermometer at least 50° C. (90° F.) above highest temperature on scale.

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass Ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. Each whole degree Centigrade or Fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° C. or 5° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Low S.P.," a serial number and the manufacturer's name or trade mark shall be etched on the thermometer.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.2° C. or 0.4° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 20° C. or 40° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Low S.P., 0 to 80° C." or "A.S.T.M. Low S.P., 30 to 180° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

Bath.

4. The minimum diameter of the bath shall be twice the diameter of the float; the minimum depth of water shall be equal to the diameter of the bath.

II. PREPARATION OF SAMPLE.

Preparation of Sample.

5. The sample shall be completely melted at the lowest possible temperature, heating only sufficiently to bring the product into a fluid condition but not above 350° F., and stirred thoroughly until it is homogeneous and free from air bubbles.

The brass collar shall be placed with the smaller end on a brass plate which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate and then with mercury. The sample shall be poured into the collar in any convenient way until slightly more than level with the top.

Asphalt and Asphalt Products.—Asphalt and asphalt products shall be cooled to room temperature, placed in water maintained at 5° C. for 5 minutes, after which the surplus material shall be removed by means of a spatula, or steel knife, which has been slightly heated. The collar and plate shall then be placed in a tin cup containing ice water maintained at 5° C., ±1° C., and left in this bath for at least 15 minutes.

Tar Products.

Tar Products.—Tar products shall be poured at a temperature of 100 to 125° C. and immediately immersed in ice water maintained at 5° C. for 5 minutes, after which the surplus material shall be removed by means of a spatula or steel knife, which has been slightly heated. The collar and plate shall then be placed in a tin cup containing ice water maintained at 5° C., ±1° C., and left in this bath for at least 15 minutes.

III. PROCEDURE.

Procedure.

6. (*a*) The bath shall be filled with water and the water heated to the temperature at which the test is to be made. This temperature shall be accurately maintained and shall at no time throughout the test be allowed to vary more than 0.5° C. from the temperature specified.

(*b*) After the material to be tested has been kept in the ice water for not less than 15 minutes nor more than 30 minutes, the collar with its contents shall be removed from the plate and screwed into the aluminum float and immersed in water at 5° C. for one minute. Any water shall then be removed from the inside of the float and the latter immediately floated in the warm bath. As the plug of material becomes warm and fluid, it is forced upward and out of the collar until the water gains entrance into the saucer and causes it to sink.

(*c*) The time in seconds between placing the apparatus on the water and when the water breaks through the material shall be determined by means of a stop watch, and shall be taken as a measure of the consistency of the material under examination.

NOTE.—Special precaution should be taken to insure the collar fitting tightly into the float and to see that there is no seepage of water between the collar and float during the test.

TENTATIVE METHOD OF TEST
FOR
FINENESS OF POWDERED COAL[1]

Serial Designation: D 197 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society, and is subject to annual revision.

ISSUED, 1924

I. APPARATUS

Sieves.

1. Sieves Nos. 40, 50, 70, 100, 140, and 200 of the United States Standard Sieve Series,[2] with close-fitting pans and covers, shall be used.

Containers.

2. (*a*) *For Collecting Gross Sample.*—The containers shall be of metal of about 8 to 10-liter capacity, provided with tightly fitting covers.

NOTE.—Two-gallon milk cans are suitable for this purpose.

(*b*) *For Collecting Laboratory Sample.*—The containers may be of metal or glass of about one-liter capacity, provided with tightly fitting covers.

II. SAMPLING

Unit of Sampling.

3. The coal pulverized, per mill, during the period of one hour shall be considered a unit for sampling.

A. Multiple System

In the multiple powdered coal system, the coal after pulverization is conveyed into bins.

Sampling.

4. Not less than 2 kg. of representative powdered coal shall be collected as it is being discharged from the pulverizer. This is best accomplished by collecting increments of not more than 200 g. at regular intervals by means of a scoop. The increments shall be placed into a can of about 8 to 10-liter capacity, provided with a tightly fitting cover.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] For detailed specifications for these sieves, see U. S. Bureau of Standards *Letter Circular No. 74.*

Preparation of Sample. 5. Th,he grosssample shall be placed on a sheet of rubber or oilcloth, and thoroughly mixed by raising first one corner of the cloth and then the other so as to roll the coal over and over at least 100 times. After mixing, the sample shall be coned and quartered. The operations of mixing, coning, and quartering shall be continued if necessary until the sample is reduced sufficiently so that all of one of the quarters weighs about 500 g., which coal shall constitute the laboratory sample. The laboratory sample shall be transferred to a metal or glass container of about one-liter capacity, provided with a tightly fitting cover.

NOTE.—The operations of mixing, coning and quartering are described and illustrated in the Standard Methods of Sampling Coal (Serial Designation: D 21) of the American Society for Testing Materials.[1]

B. Unit System

In the unit powdered coal system, the coal during and after being pulverized is at once mixed with air and delivered to the furnace. It is difficult to obtain representative samples, as it is necessary to sample the coal from a moving stream of coal and air inside the pipe between the pulverizer and the furnace. It is preferable to collect such samples from vertical pipes if possible, as in horizontal pipes considerable segregation takes place, the coarser particles tending to flow along the bottom of the pipes.

Sampling Device. 6. (*a*) The sampling device shall consist of a 1-in. thin-walled brass tube, with one end bent at a right angle or provided with a 90-deg. elbow and short length of tube. At the other end of the sampling tube a vacuum-sweeper bag shall be tightly attached. The inside of the sampling tube shall have no projections to interfere with the flow of coal.

(*b*) The sampling tube shall be inserted into the powdered coal pipe through a stuffing-box in such a manner that the opening of the sampling tube shall be directed against the stream of coal and air, and permit moving back and forth across the entire diameter of the coal pipe. If the sample must be taken from a horizontal pipe, the sampling tube shall be inserted through the top of the coal pipe, in such a manner as will permit moving the tube back and forth from top to bottom along the vertical diameter of the pipe.

Sampling. 7. In collecting the sample, the sampling tube shall be moved uniformly back and forth along the diameter of the pipe. In order to permit ready elimination of air from the bag, the vacuum-cleaner bag shall not be filled more than about one-fifth full at any time. Sampling shall be continued at regular intervals until a gross sample of not less than 5 kg. of coal is collected.

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[1] 1924 Book of A.S.T.M. Standards.

Preparation of Sample. 8. The gross sample shall be mixed, coned and quartered, and reduced in the same manner as described for the multiple powdered coal system.

III. PROCEDURE

Drying. 9. The entire laboratory sample shall be air dried in a drying oven at 10 to 15° C. above room temperature. The drying shall be continued until the loss in weight is not more than 0.1 per cent per hour.

Reducing Sample. 10. After air drying, the sample shall be thoroughly mixed by rolling over and over at least 100 times on a sheet of rubber or oilcloth, as described for the mixing of the gross sample. The sample, after mixing, shall be spread out to a depth of about $\frac{1}{2}$ in. and portions, representing a section from the top of the coal to the mixing cloth, shall be taken with a spatula at regular intervals.

Procedure. 11. A 50-g. sample of the air-dried coal shall be placed on the No. 200 sieve, to which a pan and cover shall be attached. The sieve shall be held in one hand in a slightly inclined position, so that the sample will be well distributed over the sieve, while at the same time the operator shall gently strike the side about 150 times per minute against the palm of the other hand on the up stroke. Every 25 strokes the sieve shall be turned about one-sixth of a revolution in the same direction. The sieve shall be held over a sheet of glazed white paper during the sieving operation, so as to detect any loss that might result from accidental spilling of a portion of the sample, in which case another sample shall be taken.

After sieving for one minute, the sieve pan shall be removed, and the material which has passed through the sieve discarded. The side of the sieve shall be tapped with a brush handle, and the coal adhering to the under side of the wire cloth brushed off. During the operation of tapping and brushing, the sieve cover shall remain on the sieve so as to prevent any loss of material over the side of the sieve.

NOTE.—A 1-in. bristle brush is satisfactory for brushing the under side of the wire cloth.

The sieve pan shall be replaced, and the sieving continued for two minutes; then the tapping and brushing shall be repeated, and again repeated after two minutes of additional sieving. The operation shall then be continued in the usual manner, omitting the tapping and brushing, until the amount passing through in one minute of continuous sieving is about 0.1 g. Each time, before weighing the material passing through the sieve, the side of the sieve shall be tapped with the brush handle in order to remove any material adhering to the under side of the wire cloth. The cover of the sieve shall then be removed, and the residue remaining on the sieve carefully removed. The sieve shall be inverted over a piece of glazed white paper, and the wire cloth cleaned by carefully brushing the under side. The material thus removed from the wire cloth shall be added to the residue removed from the sieve.

After cleaning the sieve, the residue shall be placed thereupon, the sieve pan and cover attached, and the sieving resumed in the usual manner, omitting the operations of tapping and brushing, until not more than 0.05 g. passes through in one minute of continuous sieving, when the sieving shall be considered to be finished. The sieve shall be inverted and cleaned as before, and the residue weighed.

12. The residue shall then be successively sieved on the Nos. 140, 100, 70, 50, and 40 sieves. Sieving shall be continued in the usual manner, omitting the tapping and brushing, until not more than 0.05 g. passes through in one minute of continuous sieving, when the sieving shall be considered finished. The sieve shall then be inverted, cleaned, and the residue weighed as described for the No. 200 sieve.

NOTE.—As the fine material which tends to clog the meshes of the sieves has been removed by sieving through the No. 200 sieve, it is not necessary to brush the under side of the wire cloth or clean the sieves during the sieving operation, as was done for the No. 200 sieve.

13. The fineness shall be calculated from the weights of the residues on the sieves, and shall be expressed as percentages of the weight of the original sample. Sieving value corrections for the No. 200 sieves, as determined by the U. S. Bureau of Standards, shall be applied to the material sieved on the No. 200 sieves. The fineness test shall be reported as follows:

	PER CENT
Retained on No. 40 sieve	....
“ “ No. 50 sieve, passing No. 40 sieve	....
“ “ No. 70 sieve, “ No. 50 sieve	....
“ “ No. 100 sieve, “ No. 70 sieve	....
“ “ No. 140 sieve, “ No. 100 sieve	....
“ “ No. 200 sieve, “ No. 140 sieve	....
“ No. 200 sieve	....

NOTE.—In applying the sieving value corrections, the graphical or analytical methods for obtaining such corrections for sieves which have been tested with a single standard sample shall be used. These methods are described in U. S. Bureau of Standards *Technologic Paper No. 42*, pp. 45–47 (1914).

Duplicate Determinations.

14. Duplicate determinations by the same operator, using the same sieves, shall check within 1 per cent on all sizes. Different

operators, using different sieves, shall check within 3 per cent on the material sieved on the No. 200 sieves.

NOTE.—Until such time as standard materials are available for determining sieving values of Nos. 140, 100, 70, 50, and 40 sieves, it is not feasible to specify check imits for the sizes as determined with these sieves, when different sieves are used.

RAPID ROUTINE METHOD BY MACHINE SIEVING

For routine testing, mechanical sieving devices, by which a number of sieves are shaken at the same time, afford a convenient method of making fineness tests. The hand-sieving method shall however be the standard method of test. The results obtained by machine sieving should be compared to those obtained by hand sieving, to determine whether the sieving action of the machine used is practically the same as by hand sieving, for the coal being sieved.

The same sieves should be used as specified for hand sieving, and these sieves should be provided with well-fitting pans and covers to prevent possible loss of material during sieving. A 50-g. sample of air-dried coal should be placed on each sieve, and the sieves shaken until not more than about 0.1 g. passes through the finest sieve of the series in the machine in one minute of continuous sieving. The sieves should then be inverted and brushed clean, as described for the No. 200 sieve in the method for hand sieving. Sieving should then be resumed until not more than 0.05 g. passes through the finest sieve of the series in the machine in one minute of continuous sieving, when the test shall be considered finished, after which the sieves should be inverted and cleaned as before, and the residues remaining on the sieves weighed. The fineness should be calculated and reported as in the hand-sieving method.

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO COKE[1]

Serial Designation: D 121 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1921; Revised, 1924

Coke.—A solid carbonaceous fuel obtained, as a coherent cellular residue, by the destructive distillation of coal and certain other carbonaceous substances such as coal tar and petroleum pitches.

Note.—In addition to carbon, as its principal constituent, it contains moisture, mineral matter (ash) and small amounts of residual volatile matter, nitrogen, and sulfur.

Beehive Coke.—Coke manufactured in beehive, rectangular or similar forms of ovens, in a horizontal bed covering the floor of such oven, where the temperature for distillation is usually secured by the combustion, within the chamber, of a portion of the material treated, the volatile matter being lost.

Note.—These ovens are heated by admission of a limited quantity of air, producing sufficient combustion to coke the coal in a specified time. In some instances heating flues are provided wherein a portion of the evolved gases are consumed. The underlying principle in the heating of the charge is internal combustion of the gases in the crown or dome of the oven, which plays an important part as a means for storage of heat and radiation to the coking mass.

By-Product Coke.—Coke manufactured in chambers or ovens, substantially rectangular in section, the height and length being materially greater than the width, and the chambers being heated externally, so that the volatile matter is saved in the form of by-products.

Note.—These ovens are heated by burning gas in the flues in the oven walls, the gas being either part of the coke-oven gas or derived from an external source. The underlying principle of the heating of the charge is external combustion, the heat so generated passing through the oven walls to the coking mass. Coke is the primary product, the volatile by-products being made available by suitable recovery apparatus.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

Gas House Coke.—Coke obtained from retorts as a by-product in the manufacture of coal gas.

Beehive Foundry Coke.—Beehive coke which is physically and chemically suitable for use in foundry cupola practice.

NOTE.—Beehive foundry coke may be either 72-hour or 48-hour coke, the former differing from the latter mainly in the greater size of its pieces.

By-Product Foundry Coke.—By-product coke which is physically and chemically suitable for use in foundry cupola practice.

NOTE.—Such coke passes over a screening device having approximately 2½-in. openings. It is not produced on any standard coking time.

Beehive Furnace Coke.—Beehive coke which is physically and chemically suitable for the reduction of iron ore in blast furnaces.

NOTE.—The breeze or fine coke smaller than approximately ¾ in. is forked or screened out. The usual coking time on a normal working schedule is four 48-hour charges and two 72-hour charges.

By-Product Furnace Coke.—By-product coke which is physically and chemically suitable for the reduction of iron ore in blast furnaces.

NOTE.—Such coke passes over a screening device with openings varying from ¾ to 1½ in., depending on local conditions at different plants. It is not produced on any standard coking time.

Coke Breeze.—Coke which will pass through a ½-in. square-hole screen.

NOTE.—Screening devices with round or rectangular openings are sometimes used, approximating the ½-in. square hole in effective screening power.

Domestic Coke.—The smaller screened sizes of coke passing approximately a 2½-in. square hole and retained on a ½-in. square-hole screen, suitable for use in domestic stoves, heaters, etc.

NOTE.—The standard sizes are quite generally sold under the names given below and the screen sizes are average, although locally varied somewhat. Screening devices with round or rectangular openings are sometimes used, approximating the sizes of square holes given below in effective screening power:

NAME	SCREEN SIZE (SQUARE HOLE)
Egg Coke	Passing 2½ in., Retained on 1¾ in.
Stove Coke	" 1¾ " " " 1¼ "
Nut Coke	" 1¼ " " " ¾ "
Pea Coke	" ¾ " " " ½ "

Dry Coke.—Coke which has been dried to constant weight at temperatures not less than 104° C. nor more than 200° C. in the case of lump coke, and between 104 and 110° C. in the case of 60-mesh coke, in accordance with methods of determining moisture contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Moisture.—The loss in weight sustained by heating coke in accordance with methods of determining moisture as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Ash.—The incombustible residue remaining after ignition of coke to constant weight in an oxidizing atmosphere under conditions described under Determination of Ash contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Volatile Matter.—That part of the coal or coke which is driven off on heating in the form of tars and gases and is determined as the percentage loss in weight less the percentage of moisture sustained on heating coke in a covered platinum crucible for 7 minutes at a temperature of 950° C., in accordance with methods of determining volatile matter as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Fixed Carbon.—The solid combustible residue remaining after heating coke in a covered platinum crucible for 7 minutes at 950° C., in accordance with methods of determining volatile matter as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Fixed carbon = 100 per cent − (Percentage of moisture + percentage of ash + percentage of volatile matter).

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO COAL[1]

Serial Designation: D 142 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

Proximate Analysis.—In the case of coal, determination by prescribed methods of moisture, volatile matter, fixed carbon (by difference), and ash.

NOTE.—Unless otherwise specified, the term "proximate analysis" does not include determinations of sulfur or phosphorus or any determinations other than those named.

Ultimate Analysis.—The quantitative determination of the elementary constituents. In the case of coal, the determination of carbon, hydrogen, and oxygen (by difference), exclusive of such portions as may be present in the incombustible residue, and the determination of sulfur and nitrogen in the entire material.

NOTE.—Part of the hydrogen and oxygen as determined is present in the moisture of the coal.

Moisture.—That constituent part, largely made up of water, in a substance, which is separated from it in analysis under specified conditions of drying. In the case of coal, the loss incurred by heating at 105° C. in accordance with the Standard Methods of Laboratory Sampling and Analysis of Coal (Serial Designation: D 22) of the American Society for Testing Materials.[2] As occurring in coal, moisture may or may not be apparent to the eye and touch.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] 1924 Book of A.S.T.M. Standards.

Volatile Matter.—In the case of coal, that portion (exclusive of moisture) which is driven off by destructive distillation under the conditions specified in the Standard Methods of Laboratory Sampling and Analysis of Coal (Serial Designation: D 22) of the American Society for Testing Materials.[1] It is not contained in the coal as such, but is formed by decomposition, and consists of combustible matter (tars and gases) and incombustible matter whose respective proportions vary with the type of coal.

Fixed Carbon.—In the case of coal, the solid residue, other than ash, obtained by destructive distillation under the conditions specified in the Standard Methods of Laboratory Sampling and Analysis of Coal (Serial Designation: D 22) of the American Society for Testing Materials.[1] It is made up principally of carbon, but contains also appreciable quantities of sulfur, hydrogen, nitrogen and oxygen.

Ash.—Inorganic residue remaining after complete ignition of combustible substances. In the case of coal, the residue after igniting under the conditions specified in the Standard Methods of Laboratory Sampling and Analysis of Coal (Serial Designation: D 22) of the American Society for Testing Materials.[1]

NOTE.—The ash as thus determined is less in amount than that of the actual incombustible constituents of dry coal owing to chemical changes which occur in these by burning.

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[1] 1924 Book of A.S.T.M. Standards.

TENTATIVE METHODS OF TESTING SMALL CLEAR SPECIMENS OF TIMBER[1]

Serial Designation: D 143 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1924.

The everyday use of timber for multitudinous purposes makes manifest a continual need of data on its mechanical properties. The great variety of species, the variability of the material, the continually changing conditions of supply, the many factors affecting test results, all combine to make the technique of testing wood unique in its complexity.

In the preparation of this procedure for testing small clear specimens, consideration was given both to the desirability of adopting methods which would yield results comparable to those already available and to the possibility of embodying such improvements as experience has shown desirable. In view of the many thousands of tests made under a single comprehensive plan by the U. S. Forest Service, the Forestry Branch of the Department of the Interior, Canada, and other similar organizations, the procedure naturally conforms closely to the methods used by these institutions. This procedure is the outgrowth of a study of both American and European experience and methods. Its general adoption will tend toward a world-wide unification of results, permitting an interchange and correlation of data, and will establish the basis for a cumulative body of fundamental information on the timber species of the world.

The methods under consideration represent the entire procedure from selection of the trees to the manipulation of the test, thus controlling factors, such as the size and proportion of test specimens and rate of loading, which may influence results. No attempt has been made to cover methods of computation and analysis, as these questions may be considered independently at any time. Such sample data and computation sheets and cards have been incorporated, however, as were thought to be of assistance to the investigator in systematizing records.

Purpose of Tests.

1. Tests on small clear specimens of wood are made to afford:

(*a*) Data for comparing the mechanical properties of various species.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1925, to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, Forest Products Laboratory, Madison, Wis.

(*b*) Data for the establishment of correct strength functions which, in conjunction with results of tests of timbers in structural sizes,[1] afford the basis for fixing allowable stresses.

(*c*) Data upon which to determine the influence on the mechanical properties of such factors as density, locality of growth, position in cross-section, height of timber in the tree, change of properties with seasoning, and change from sapwood to heartwood.

Kind of Tests.

2. The principal mechanical tests are static bending, compression parallel to grain, impact bending, compression perpendicular to grain, hardness, shear parallel to grain,[2] tension perpendicular to grain, cleavage, and tension parallel to grain. These tests are made on both green and air-dry material as hereinafter specified. In addition, such physical properties as specific gravity, radial shrinkage, tangential shrinkage, and shrinkage in volume are determined.

MATERIAL.

I. COLLECTION.

(*A*) *Selection.*

Authentic Identification

3. The material shall be from trees selected in the forest by one qualified to indentify the species.

Selection and Number of Trees.

4. For each species to be tested from a given locality, at least five representative trees of merchantable size and of approximately average age shall be selected.

Selection and Number of Bolts.

5. The material from five trees of each species from a given locality shall be selected as follows:

(*a*) From one tree, the entire merchantable bole, if not over 16 ft. in length;[3] if over 16 ft. in length, four 4-ft. sections or bolts, the first to be taken at the stump, the second and third at distances of one-eighth and three-eighths, respectively, of the merchantable length above the stump or as near thereto as possible; and the fourth at the top of the merchantable length.

(*b*) From two trees, the 8-ft. section next above the 8-ft. butt log.

(*c*) From two trees, the 4-ft. section next above the 12-ft. butt log.

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[1] See Tentative Methods for Conducting Static Tests of Timbers in Structural Sizes (Serial Designation: D 198 – 24 T) of the American Society for Testing Materials, p. 976.

[2] The test for shearing strength perpendicular to the grain (sometimes termed "vertical shear") is not included as one of the principal mechanical tests since in such a test the strength is limited by the shearing resistance parallel to the grain.

[3] This tree is intended to furnish test material for studying, among other things, the variation of properties with height in trees and provides for this purpose a 4-ft. section from different heights. Experience has shown that four sections or bolts, each 4 ft. in length, will usually be sufficient for studying the influence of height in tree on the mechanical properties.

Selection from Small Trees.

6. In cases where the logs or bolts are over 36 in. in diameter, a single flitch 6 in. in thickness, taken through the pith in a north and south direction and representing the full diameter of the log, may be substituted, in the same length, for the full log or bolt specified in Section 5.

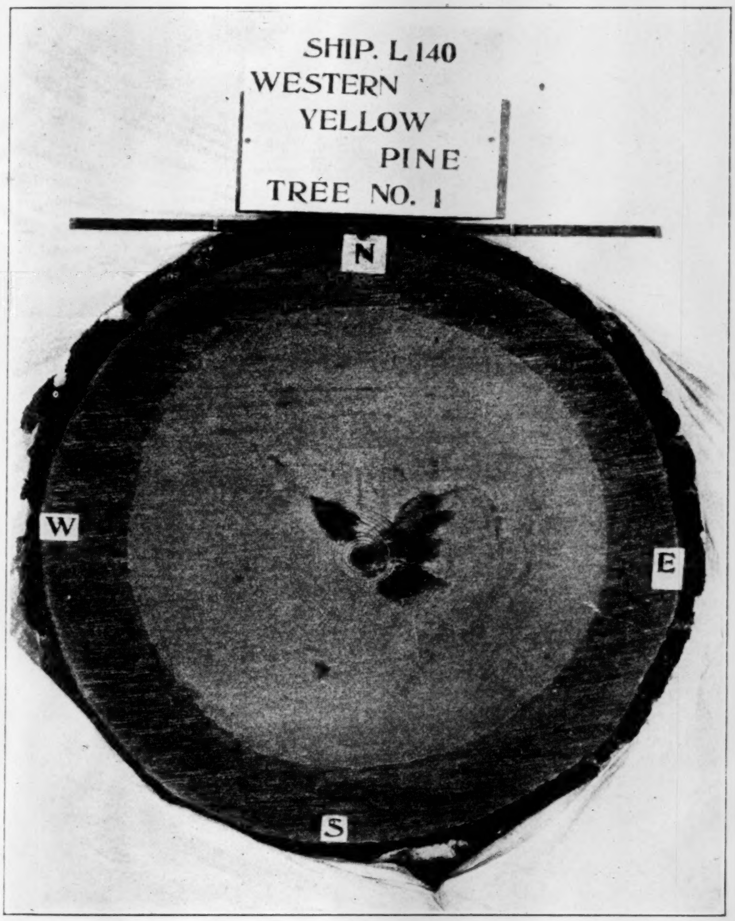

FIG. 1.—Section of Log Selected for Test Material.

Substitution of Flitches for Bolts.

7. When the trees are relatively small in diameter, material in addition to that provided for in Sections 5 and 6 shall be collected, whenever possible, to insure a sufficient number of tests to give a good average for the species.

(*B*) *Field Marking.*

Tree Designation. 8. Each tree shall be given an arabic number, the numbering in any given shipment to be consecutive for trees of a given species.

Bolt Designation. 9. Each 4 ft. of length of a tree or log shall be considered a "bolt." Bolts shall be designated by small letters, beginning with *a* for the 4-ft. section next above the stump. Bolt letters, therefore, indicate position with respect to height in tree.

Manner of Marking. 10. The tree number and bolt designation shall be plainly marked upon each log selected by the collector. Thus the 16-ft. butt log of Tree No. 2 would be designated *2abcd*. Steel dies are recommended for marking the butt end of the logs.

Cardinal Point Indicated. 11. The north side of each log shall be indicated in some convenient manner.

Shipment Number. 12. All material collected from a given locality and shipped at one time shall be given a shipment number or other designation.

TABLE I.—SHIPMENT DESCRIPTION FIELD NOTES.

Project No., *124* Shipment No., *323*
Tree No., *10* Species, *Lodgepole pine*
Locality cut: State, *Montana* County, *Jefferson*
Township, *6 N., R. 7 W., M. P. M.* Date cut, *Oct. 10, 1914*
Slope, *Moderate* Absolute elevation, *6600 ft.* Aspect, *southeasterly*
Undergrowth, *None* Soil, *Deep, fresh-decomposed granite*
Height, *73.9 ft.* Seedling or sprout, *Seedling* Age, *140*
Crown, *Length 25 ft., width 12 ft.* D.B.H. *11.1 in.*
Stem, *Sound, smooth, clear, length 20 ft.* Date sawed, *Oct. 10, 1914*
How and when transported from woods, *By sleigh and wagon, Oct. 13 to 15, 1914.*

LIST OF SPECIMENS SAWED.

Log No.	Bolts.	Length, ft.	Diameter Inside Bark.		Volume.	Feetage, b. m.	Weight, Oct. 15, lb.
			Butt, in.	Top, in.			
1	bcd	12.1	11	9.6	..	..	336
2	efg	12.1	9.6	8.9	..	..	289
3	hij	12.1	8.9	7.7	..	..	242
4	klm	12.1	7.7	6.1	..	..	176
5	nop	12.1	6.1	3.1	..	..	95

REMARKS: *Stump height, 1.0 ft. Butt off on account of frost crack 3.0 ft. Length of top above last section taken, 9.4 ft. Total age, 140 years. Tree was dominant throughout life. Rate of growth, regular and good average for Site I. Lower slope type, although of more than average height for the age and diameter found on poorer sites.*

(*C*) *Field Descriptions.*

Field Description. 13. (*a*) Complete field notes describing the material shall be fully and carefully made by the collector. These notes shall in general, supply data as outlined in Table I.

(*b*) Photographs of the standing trees selected shall be taken.

(*D*) *Preparation for Shipment.*

Preparation for Shipment.

14. (*a*) The bark will be left on each log, and care shall be taken to keep the bark intact. The ends of the logs shall be carefully painted to retard or prevent end drying and end checking.

(*b*) Record shall be made of the shipment routing, bill of lading, kind of shipment, date of shipment, and condition of material when shipped.

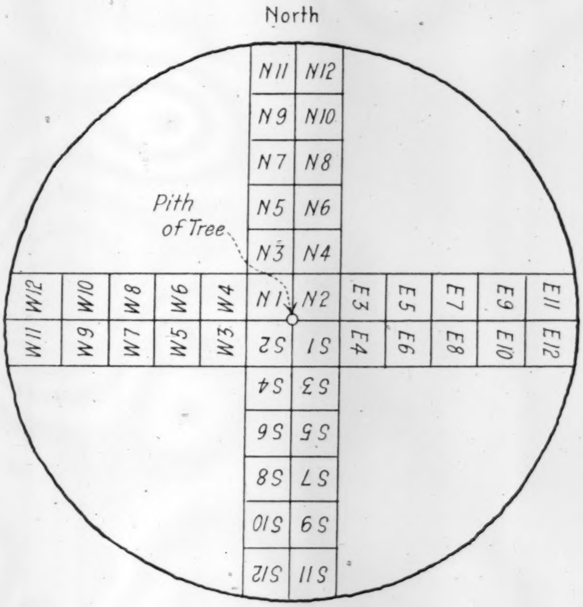
North
Pith of Tree
N11
N12
N9
N10
N7
N8
N5
N6
N3
N4
W12
W10
W8
W6
W4
N1
N2
E3
E5
E7
E9
E11
W11
W9
W7
W5
W3
S2
S1
E4
E6
E8
E10
E12
S4
S3
S6
S5
S8
S7
S10
S9
S12
S11

FIG. 2.—Sketch Showing Method of Cutting up the Bolt and Marking the Sticks.

(*c*) Record shall also be made of date of receipt of shipment at destination, its condition and method of storage.

II. DISPOSITION.

(*A*) *Storage of Logs at Destination.*

Storage of Logs.

15. Material shall not be kept in the bolt or log form long enough to permit damage by checks, decay, stains, or insect attack. The

logs shall be piled on skids, free from contact with the soil, and shall not be stored where subjected to artificial heat. In addition they should preferably be protected from the sun.

(B) *Photographing, Sawing and Final Marking.*

Photographing Ends of Bolts.

16. The top end of each *d* or *c-d* bolt shall be photographed. It is suggested that a rule be so placed on the log as to indicate the scale of the photograph and that the cardinal points be indicated on the cross-section. Fig. 1 shows a photograph of this kind.

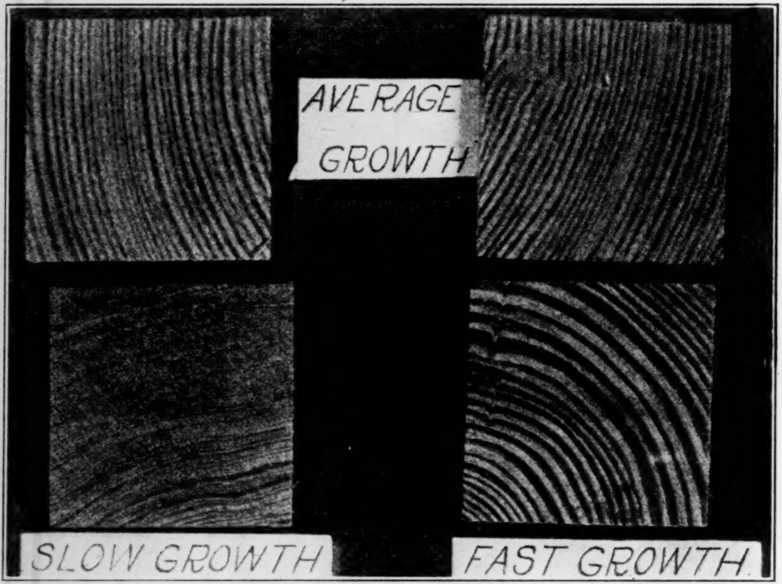

FIG. 3.—Cross-Sections of Bending Specimens Showing Different Rates of Growth of Longleaf Pine (2 by 2-in. Specimens).

Sawing of Bolts.

17. (*a*) All bolts shall be marked on the top end into 2½ by 2½-in. squares as shown in Fig. 2, and sawed into nominal 2½ by 2½-in. sticks. The letters *N*, *E*, *S*, and *W* indicate the cardinal points.

(*b*) When flitches are substituted for bolts (Section 6), the same general marking and numbering scheme of Paragraph (*a*) shall be followed in so far as it is applicable.

Marking of Test Sticks.

18. All test sticks shall bear the shipment number, the tree number, stick number, and bolt designation, to be known respectively

as Shipment No., Piece No., Stick No., and mark. Thus 400-1-*N*4*d* represents Stick *N*4 of Bolt *d*, Tree 1, Shipment 400.

(*C*) *Matching for Air-dry Tests.*

Composition Bolts.

19. In the tests made to determine the effect of air-drying on strength, the sticks from the *c* bolt shall be interchanged with those of the *d* bolt of the same tree to form two composition bolts, each composition bolt being complete and being made of equal portions of *c* and *d* bolts.[1] The sticks from one of these composition bolts shall be tested green and those from the other shall be tested after air drying. The sticks tested either green or air dry shall be regarded as if they were from the same bolt.

Schedule for Forming Composition Bolts.

20. The division of green and air-dry sticks shall be made according to the following schedule in which the numbers refer to stick numbers:

Composition Bolt to be Tested Green.—

Lower bolt *c*	1		4, 5		8, 9		
Upper bolt *d*		2, 3		6, 7		10, etc.	

Composition Bolt to be Air Dried and Tested.—

Lower bolt *c*		2, 3		6, 7		10, etc.
Upper bolt *d*	1		4, 5		8, 9	

(*D*) *Disposition of Sticks.*

Green Material.

21. The sticks ($2\frac{1}{2}$ by $2\frac{1}{2}$ in. by 4 ft.) to be tested green shall be kept in an unseasoned condition while awaiting preparation for test by being stored in a framed pit or other suitable container, where they shall be close piled and covered with damp sawdust or in some other suitable manner. As material is required for test, it shall be removed from this pit, or container, surfaced on all four sides to 2-in. by 2-in. in cross-section, sawed to test size and kept covered with a damp cloth, in an air-tight container at a temperature of about 70° F. (as nearly as practicable) until the time of test. Care shall be taken to avoid as much as possible the storage of green material in any form. Sticks to be tested in a green condition should usually not be sawed from the log form in quantities greater than is required to meet the

---

[1] The 8-ft. section (*c* and *d* bolts) from each of the two trees provided for under Section 5 (*b*) is intended for tests to determine the effect of air drying on strength.

testing demands for from a few days to not more than two weeks, depending on the prevailing conditions.

Air-dry Material. 22. (*a*) The ends of the sticks to be air dried ($2\frac{1}{2}$ by $2\frac{1}{2}$ in. by 4 ft.) shall be dipped in melted paraffin or other substance suitable to retard checking. The material shall be piled so as to have a space of at least $\frac{1}{2}$ in. on each side of each stick to permit circulation of air. The material shall be stored in a place allowing free access of air, but protected from sunshine, rain, snow, and moisture from the ground. The sticks in drying shall not be subjected to artificial heat.

(*b*) All of the sticks from each composite bolt to be air dried shall be weighed when stored and at sufficiently frequent intervals thereafter to get accurate data on the progress of seasoning. No material shall be considered thoroughly air dried and properly conditioned for testing until practically constant weight has been reached. (Wood absorbs and gives off moisture with changing atmospheric conditions, consequently it never comes to absolutely constant weight.)

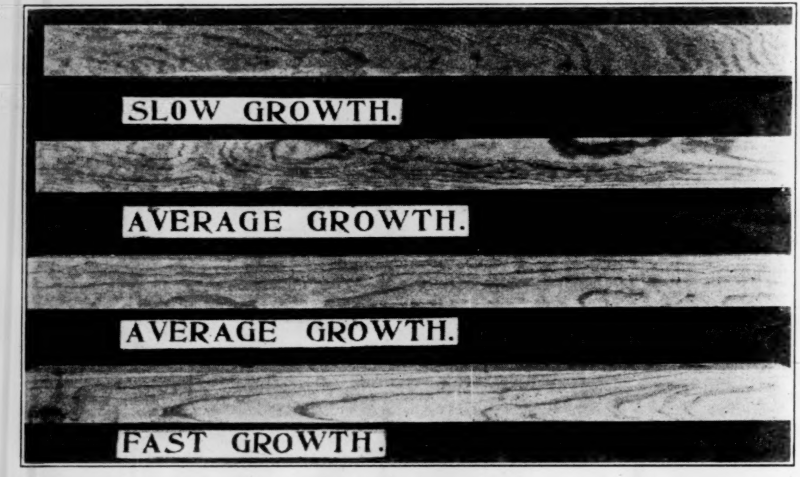

FIG. 4.—Tangential Surfaces of Bending Specimens of Different Rates of Growth of Jeffrey Pine (2 by 2 by 30-in. Specimens).

(*c*) When the material has reached equilibrium, moisture sections 1 in. in length shall be taken from about 10 per cent of the sticks to determine the actual moisture content. These moisture specimens shall be cut not less than 1 ft. from the ends of the sticks, and in such a way as to prevent any appreciable loss of material for testing. When thoroughly air dry, the material shall be surfaced on four sides to 2 in. by 2 in. in cross-section and tested.

TESTING.

III. ORDER, SELECTION, AND NUMBER.

(*A*) *Order.*

Order of Tests.

23. The order of tests in all cases shall be such as to eliminate as far as possible from the comparisons the effect of changes in the specimen due to such factors as storage and weather conditions.

(*B*) *Selection.*

Preference in Selecting Specimens.

24. In case the material from a given bolt should be insufficient to furnish all the test specimens hereinafter required, the preferential order of mechanical tests to be used in selecting specimens shall be as follows: Static bending, compression parallel to grain, impact bending, compression perpendicular to grain, hardness, shear parallel to grain, tension perpendicular to grain, cleavage, and tension parallel to grain.

Test Pieces from Bending Specimens After Failure.

25. In many cases where a shortage of material exists, certain test specimens may be taken from the uninjured portion of the static and impact bending specimens remaining after test, provided proper care is used in the selection.

Quality of Test Material.

26. Only clear straight-grained material, free from decay and other defects, shall be used for the tests. However, small knots and other similar defects may be admitted in such specimens as static bending when their location is such that it is certain they will not in any way influence the failure or otherwise affect the strength of the specimen.

(*C*) *Number of Tests for Each Bolt.*

Static Bending.

27. One static bending specimen shall be taken from each pair of sticks. A pair consists of two adjacent sticks equi-distant from the pith, as *W*3 and *W*4, Fig. 2. In the composite bolts tested to afford a comparison of the strength of green and air-dry material, the pair of sticks shall be constituted as above, except that the sticks in this case will be from different bolts. Thus *W*3*d* and *W*4*c* constitute one pair of sticks to be tested green, and *W*3*c* and *W*4*d* the corresponding pair to be tested air dry (Section 20).

Compression Parallel to Grain.

28. One compression-parallel-to-grain specimen shall be taken from each stick. Load-compression curves shall be taken on 20 per cent of the specimens.

Impact Bending.

29. Eight impact-bending specimens shall be taken from each bolt, selection being made from the sticks remaining after obtaining the static bending tests. Two of the specimens shall be selected from

near the pith, two from near the periphery, and four which are representative of the cross-section.

Compression Perpendicular to Grain. 30. One compression-perpendicular-to-grain specimen shall be taken from each of 50 per cent of the sticks selected for static bending.

Hardness. 31. One hardness specimen shall be taken from each of the other 50 per cent of the static-bending sticks.

Shear Parallel to Grain. 32. Eight shear-parallel-to-grain specimens shall be selected from the unused portion or ends of four sticks from which bending specimens have been selected. Two specimens shall be taken from near the pith, two from near the periphery, and four that are representative of the average growth of the cross-section of the bolt. One of each pair of specimens from the same stick shall be tested in radial shear (surface of failure radial) and the other in tangential shear (surface of failure tangential).

Tension Perpendicular to Grain. 33. Eight tension-perpendicular-to-grain specimens shall be selected from four sticks in a manner similar to that for shear (Section 32). One of each pair of specimens from the same stick shall be tested in radial tension (surface of failure radial) and the other in tangential tension (surface of failure tangential).

Cleavage Perpendicular to Grain. 34. Eight cleavage specimens shall be selected from four sticks in a manner similar to that for shear (Section 32). One of each pair of specimens from the same stick shall be tested in radial cleavage (surface of failure radial) and the other in tangential cleavage (surface of failure tangential).

Tension Parallel to Grain. 35. Four tension-parallel-to-grain specimens shall be chosen of which one shall be selected from near the pith, one from near the periphery and two which are representative of the cross-section.

Specific Gravity and Shrinkage in Volume. 36. Six specific gravity and shrinkage-in-volume specimens shall be selected from the unused portion of bending or tension-parallel-to-grain sticks, selected so as to give one from near the pith, one from near the periphery, and four that are representative of the average growth of the cross-section of the bolt. These specimens shall be selected only from the sticks to be tested in a green condition.

Radial Shrinkage. 37. Two radical shrinkage specimens shall be obtained from each *d* bolt. They shall be cut from the "sectors" or "quadrants" remaining after sawing (Fig. 2) or from disks cut from near the end of the bolt. When a disk is used, care must be taken to see that it is green, and has not been affected by shrinking and checking which is common near the end of the bolt. The specimens shall not be surfaced. Radial shrinkage specimens shall be cut with their width in the radial direction. One shall be taken from the heartwood, and the other from near the periphery. When possible, the second shall consist entirely of sapwood.

Tangential Shrinkage.

38. Two tangential shrinkage specimens shall be obtained from each *d* bolt. They shall be selected at the same time and in a manner similar to radial-shrinkage specimens (Section 37), except the width shall be in a tangential direction. The specimens shall not be surfaced. One shall be taken from the heartwood, the other from near the periphery and when possible shall consist entirely of sapwood. The heartwood and the sapwood specimens shall be taken adjacent to the respective specimens selected for radial shrinkage.

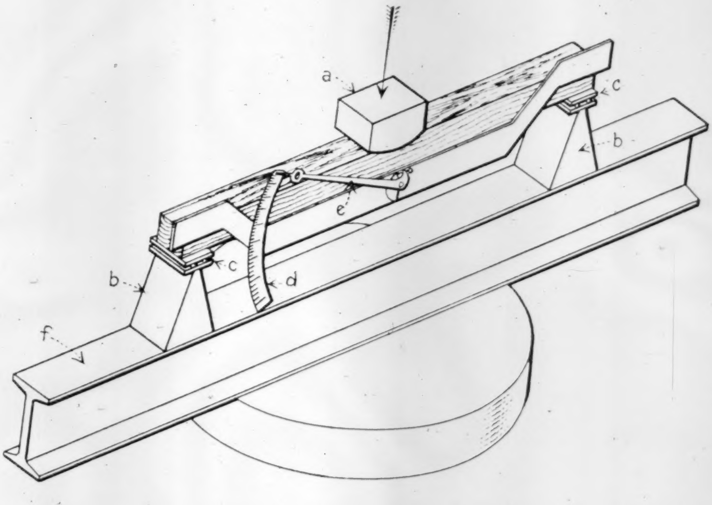

FIG. 5.—Diagrammatic Sketch of Method of Conducting Static Bending Test.

IV. GENERAL INSTRUCTIONS.

(*A*) *Photographs of Sticks.*

Sticks to be Photographed.

39. Four of the bending sticks from each species shall be selected for photographing, as follows: 2 average growth, 1 fast growth, and 1 slow growth. These sticks shall be photographed in cross-section and on the radial and tangential surfaces. Fig. 3 is a typical photograph of the cross-section of test specimens and Fig. 4 of the tangential surface of bending specimens.

(*B*) *Control of Moisture Content.*

Control of Moisture Content.

40. As previously specified (Section 22) sticks for test in the air-dry condition shall be brought to practically constant weight

before test. Tests shall then be carried out in such a manner that large changes in moisture content will not occur. (For instance, in ordinary heated rooms the relative humidity is usually below 30 per cent. If wood which has been dried to practically constant weight under the condition specified by Section 22 is brought into such a room, a considerable and rather rapid drying out will occur.) To prevent such changes, the testing room and rooms for the preparation of test specimens should preferably have some means of humidity control.

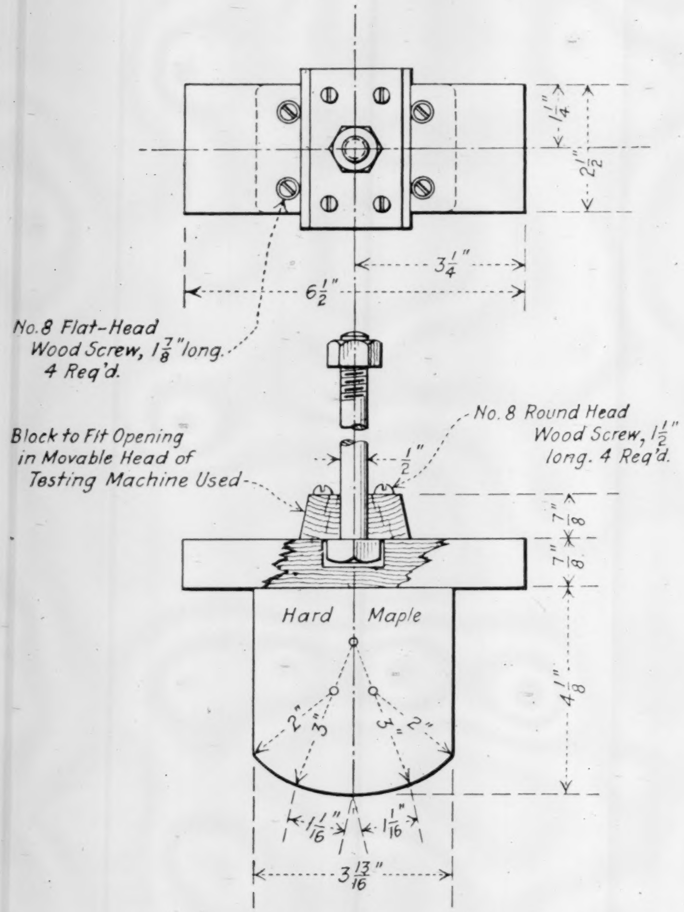
1 1/4"
2 1/2"
3 1/4"
6 1/2"
No. 8 Flat-Head Wood Screw, 1 7/8" long. 4 Req'd.
No. 8 Round Head Wood Screw, 1 1/2" long. 4 Req'd.
Block to Fit Opening in Movable Head of Testing Machine Used
1/2"
7/8"
7/8"
Hard Maple
4 1/8"
2"
3"
3"
2"
1 1/16"
1 1/16"
3 13/16"

FIG. 6.—Details of Bearing Block for Bending Tests.

(*C*) *Record of Heartwood and Sapwood.*

Proportion of Sapwood.

41. The estimated proportion of sapwood present shall be recorded for each test specimen.

V. PROCEDURE.

(*A*) *Static Bending.*

Size of Specimens.

42. The static bending tests shall be made on nominal 2 by 2 by 30-in. specimens. The actual height and width at the center, and the length shall be measured.

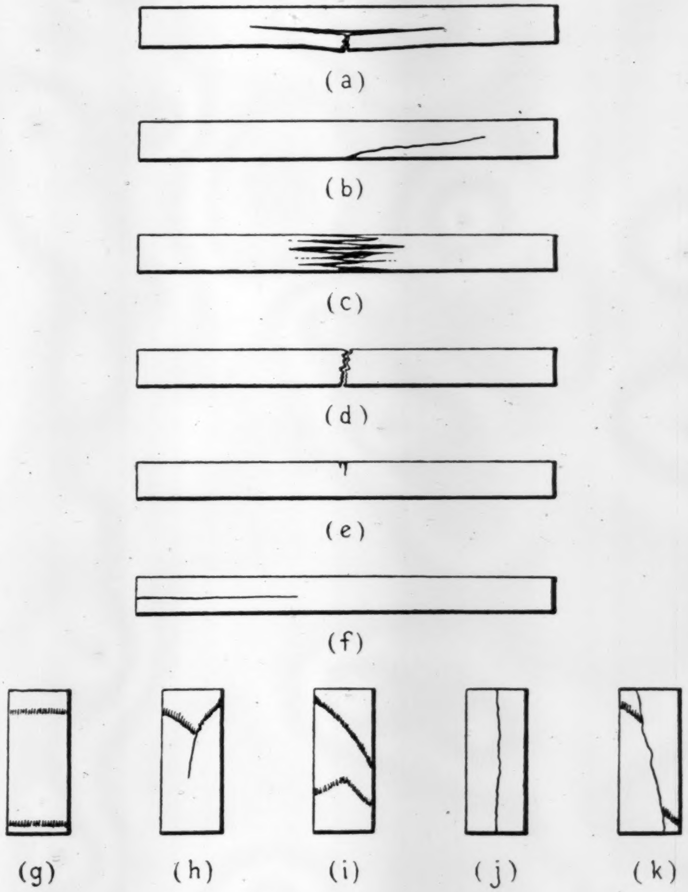

FIG. 7.—Types of Failures: *a* to *f*, Bending; *g* to *k*, Compression Parallel to Grain.

Loading Span and Supports.

43. Center loading and a span length of 28 in. shall be used. Both supporting knife edges shall be provided with bearing plates and rollers having a total thickness of approximately $1\frac{1}{4}$ in. in order to

bring the neutral plane of the test specimen about $2\frac{1}{4}$ in. from the knife edges (Fig. 5.)

Bearing Block. 44. A bearing block of the form and size of that shown in Fig. 6 shall be used for applying the load.

Placement of Growth Rings. 45. The specimen shall be placed so that the load will be applied through the bearing block to the tangential (flat-sawn) surface nearest the pith.

Rate of Application of Load. 46. The load shall be applied continuously throughout the test at a rate of 0.10 in. per minute.

Load-Deflection Curves. 47. (*a*) Load-deflection curves shall be taken to or beyond the maximum load for all static bending tests. In one-third of the tests, the curves shall be continued to a 6-in. deflection, or until the specimen fails to support a load of 200 lb.

(*b*) Deflections of the neutral plane at the center of the length shall be taken with respect to points in the neutral plane above the supports.

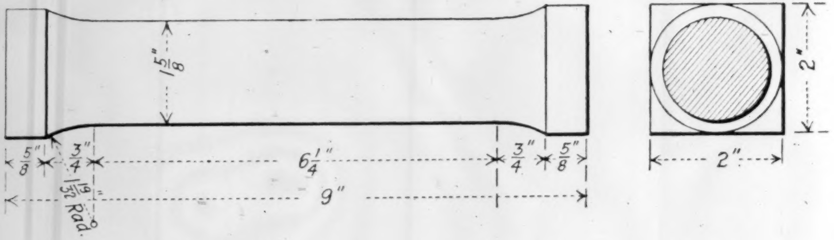

FIG. 8.—Compression-Parallel-to-Grain Test Specimen Special Form.

(*c*) Within the elastic limit, deflection readings shall be taken to 0.0025 in. After the elastic limit has been reached, less refinement is necessary in observing deflections, and these may then be read directly to the nearest 0.01 in. by means of a wire stretched across a scale. Fig. 5 illustrates the method of test and type of deflectometer recommended for deflections up to 1 in.

(*d*) The load and deflection of first failure, the maximum load, and points of sudden change shall be shown on the curve sheet[1] although they may not occur at one of the regular load or deflection increments.

Description of Failures. 48. Bending failures shall be classified according to the appearance of the fractured surface and according to the manner in which the failure develops. The fractured surfaces may be roughly divided into brash and fibrous, the term "brash" indicating an abrupt failure and the term "fibrous" indicating a fracture showing splinters. The test failures shall be classified and described as follows:

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[1] See Fig. 1 of the Appendix for a sample static bending data sheet form. Fig. 2 of the Appendix shows a sample computation data card.

Simple tension (see Fig. 7*a*);
Cross grain[1] tension (see Fig. 7*b*);

> The presence of cross grain having a slope which deviates more than 1 in 20 from the longitudinal edges of the specimen shall be cause for culling the test.

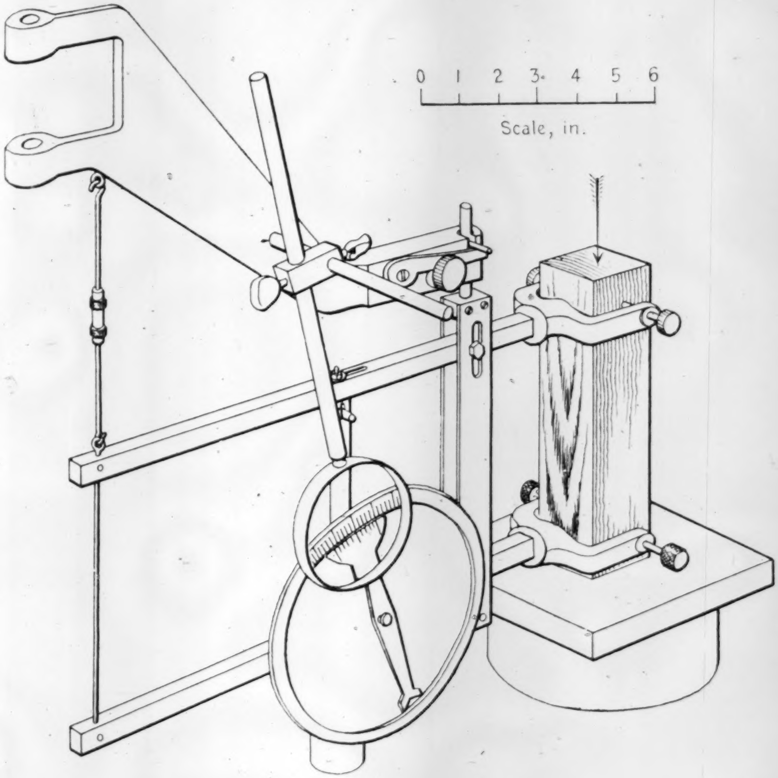

FIG. 9.—Diagrammatic Sketch of U. S. Forest Service Compressometer and Method of Conducting Compression-Parallel-to-Grain Test.

Splintering tension (see Fig. 7*c*);
Brash tension (see Fig. 7*d*);
Compression (see Fig. 7*e*);
Horizontal shear (see Fig. 7*f*).

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[1] The term "cross grain" shall be considered to include all deviations of grain from the direction of the longitudinal axis or longitudinal edges of the specimen. It should be noted that spiral grain may be present even to a serious extent without being evident from a casual observation.

In case two or more kinds of failures develop, all shall be described in the order of their occurrence; thus, compression followed by splintering tension. The failure shall be sketched on the data sheet.

Weight and Moisture Content. 49. The specimen shall be weighed after test and a moisture section 1 in. in length shall be cut near the failure.

(B) *Compression Parallel to Grain.*

Size of Specimens. 50. The compression-parallel-to-grain tests shall be made (1) on nominal 2 by 2 by 8-in. specimens, or (2) on specimens of the special form shown in Fig. 8. The actual cross-section dimensions, or the diameter at minimum section, and the length shall be measured.

Advantage of Special Form. 51. The specimen with reduced cross-section (Fig. 8) will usually require less care preparatory to test in order to prevent crushing at the ends than the specimen with uniform cross-section throughout the length.

End Surfaces Parallel. 52. Care shall be used in preparing the compression-parallel-to-grain test specimens to make the end surfaces parallel.

Spherical Bearing. 53. A spherical bearing block shall be used and so adjusted for each test as to obtain a uniform distribution of load over the ends of the specimen.

Rate of Application of Load. 54. The load shall be applied continuously throughout the test at a rate of 0.024 in. per minute.

Load-Compression Curves. 55. (*a*) Load-compression curves shall be taken for a 6-in. central gage length on 20 per cent of the specimens. Load-compression readings shall be continued until the elastic limit is well passed, as indicated by the curve.[1] On the other 80 per cent of the specimens the maximum load only will be obtained.

(*b*) Deformations shall be read to 0.0005 in.

(*c*) Fig. 9 illustrates a type of compressometer, using a Johnson dial, which has been found satisfactory for wood testing.

Position of Test Failures. 56. In order to obtain satisfactory and uniform results, it is necessary that the failures be made to develop in the body of the specimen. With specimens of uniform cross-section, this result can best be obtained when the ends are at a very slightly lower moisture content than the body. With green material it will usually suffice to close-pile the specimens, cover the body with a damp or wet cloth and expose the ends for a short time. For air-dry material, it may sometimes be advisable to pile the specimens in a similar manner and place them in a desiccator should the failures in test indicate that a slight end drying is necessary.

---

[1] See Fig. 4 of the Appendix for a sample compression-parallel-to-grain data sheet form. Fig. 3 of the Appendix shows a sample computation data card.

Description of Failures.

57. Compression failures shall be classified and described according to their appearance, as follows:

(*a*) *Crushing.*—This term shall be used when the plane of rupture is approximately horizontal. See Fig. 7(*g*).

(*b*) *Wedge Split.*—The direction of the split, that is whether radial or tangential, should be noted. See Fig. 7(*h*).

(*c*) *Shearing.*—This term shall be used when the plane of rupture makes an acute angle with the axis of the specimen. See Fig. 7 (*i*).

(*d*) *Splitting.*—See Fig. 7(*j*).

(*e*) *Compression and Shearing Parallel to Grain.*—This failure usually occurs in cross-grained pieces, and should be culled as a compression test. See Fig. 7(*k*). The failure shall be sketched on the data sheet. In addition the location of the failure shall be recorded along with its description.

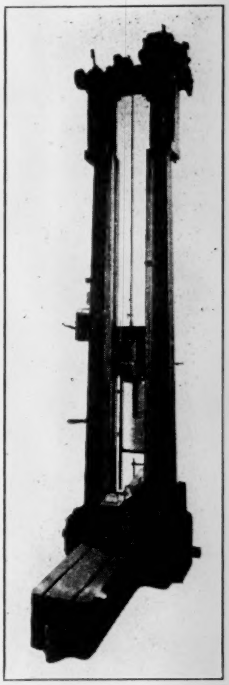

FIG. 10.—Hatt-Turner Impact Machine, Illustrating Method of Conducting Impact Bending Test.

Weight and Moisture Content.

58. The specimen shall be weighed after test and a moisture section 1 in. in length shall be cut from the body near the failure.

Ring and Summer Wood Measurement.

59. After the moisture section has been weighed, the number of rings per inch and the proportion of summer wood shall be measured over a representative inch of cross-section. In determining the proportion of summer wood, it is essential that the end surface be prepared so as to permit accurate summer wood measurement. When the fibers are broomed over at the ends from sawing, a light sanding, planing, or similar treatment of the ends is recommended.

(*C*) *Impact Bending.*

Size of Specimens.

60. The impact bending tests shall be made on nominal 2 by 2 by 30-in. specimens. The actual height and width at the center and the length shall be measured.

Loading and Span.

61. Center loading and a span length of 28 in. shall be used.

Bearing Block.

62. A metal tup of curvature corresponding to the bearing block shown in Fig. 6 shall be used in applying the load.

Placement of Growth Rings.

63. The specimen shall be placed so that the load will be applied through the bearing block to the tangential or flat-sawn surface nearest the pith.

Method of Test. 64. The tests shall be made by increment drops in a Hatt-Turner impact or similar machine. See Fig. 10. The first drop shall be 1 in., which shall be increased by 1-in. increments until a height of 10 in. is reached. A 2-in. increment shall then be used until complete failure occurs or until a 6-in. deflection is reached.

Weight of Hammer. 65. A 50-lb. hammer shall be used when, with drops up to the capacity of the machine (about 68 in. for the small Hatt-Turner impact machine), it is practically certain that complete failure or a 6-in. deflection will result for all specimens of a species. For all other cases a 100-lb. hammer shall be used.

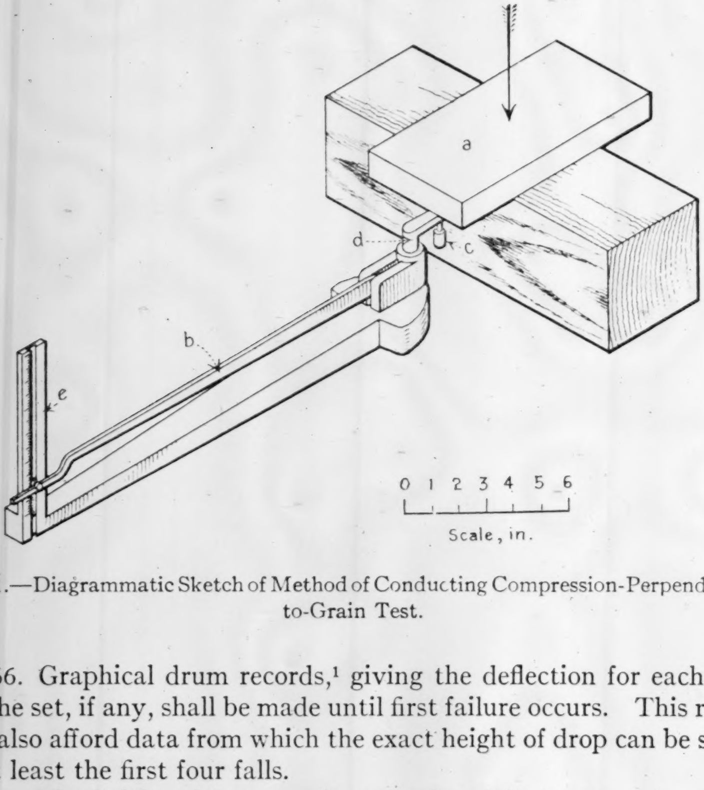

FIG. 11.—Diagrammatic Sketch of Method of Conducting Compression-Perpendicular-to-Grain Test.

Deflection Records. 66. Graphical drum records,[1] giving the deflection for each drop and the set, if any, shall be made until first failure occurs. This record shall also afford data from which the exact height of drop can be scaled for at least the first four falls.

Drop Causing Failure. 67. The height of drop causing complete failure, or a 6-in. deflection, shall be observed for each specimen.

Description of Failure. 68. The failure shall be sketched on the data sheet[2] and described in accordance with the directions for static bending under Section 48.

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[1] See Fig. 5 of the Appendix for a sample drum record.

[2] See Fig. 7 of the Appendix for a sample impact bending data sheet form. Fig. 6 of the Appendix shows a sample computation data card.

69. The specimen shall be weighed after the test and a moisture section 1 in. in length shall be cut near the failure. **Weight and Moisture Content.**

(*D*) *Compression Perpendicular to Grain.*

70. The compression-perpendicular-to-grain tests shall be made on nominal 2 by 2 by 6-in. specimens. The actual height, width, and length shall be measured. **Size of Specimens.**

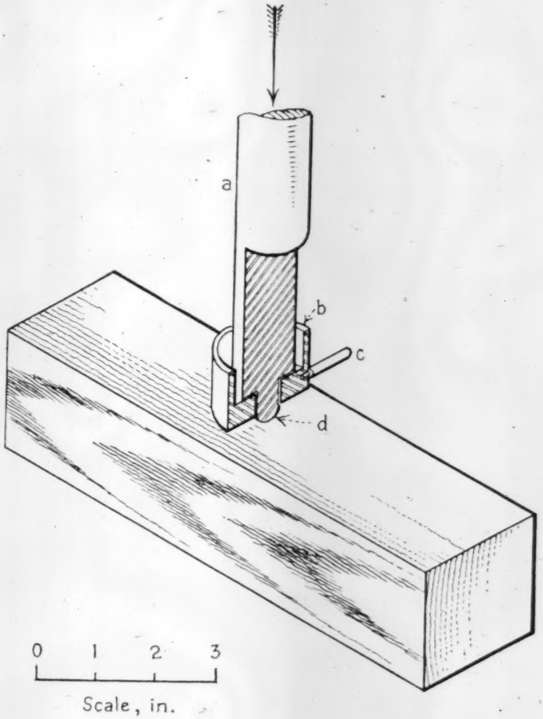

FIG. 12.—Diagrammatic Sketch of Method of Conducting Hardness Test.

71. The load shall be applied through a metal bearing plate 2 in. in width, placed across the upper surface of the specimen at equal distances from the ends and at right angles to the length. (See Fig. 11.) **Loading.**

72. The specimen shall be placed so that the load will be applied through the bearing plate to a radial (quarter-sawn) surface. **Placement of Growth Rings.**

73. The load shall be applied continuously throughout the test at a rate of 0.024 in. per minute. **Rate of Application of Load.**

Load-Compression Curves. 74. (*a*) Load-compression curves[1] shall be taken for all specimens up to 0.1-in. compression, after which the test will be discontinued.

(*b*) Deflection readings shall be taken to 0.001 in.

Weight and Moisture Content. 75. The specimen shall be weighed after test and a moisture section 1 in. in length shall be cut adjacent to the part under load.

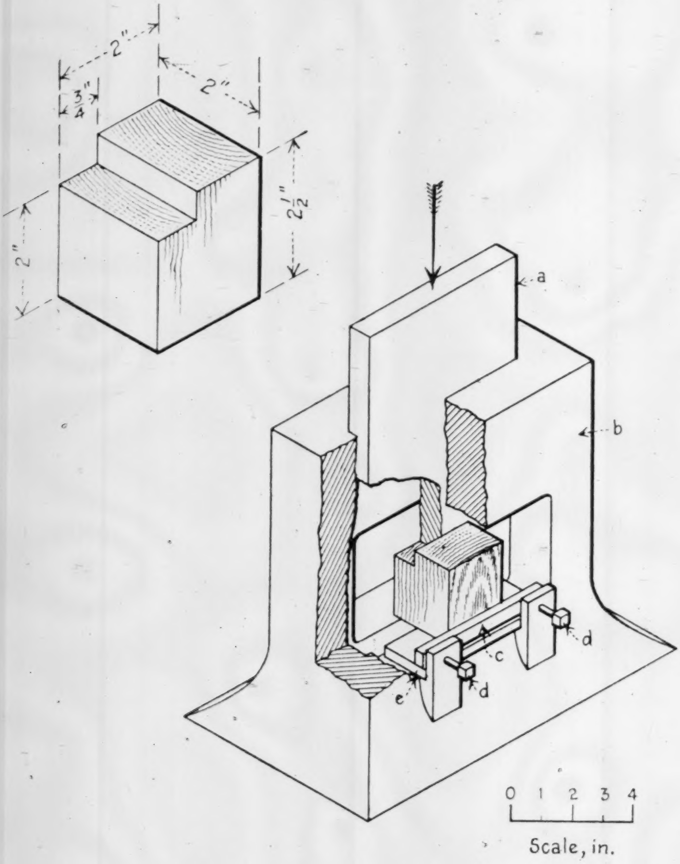

FIG. 13.—Diagrammatic Sketch of Method of Conducting Shear-Parallel-to-Grain Test, with Details of Test Specimen.

(*E*) *Hardness.*

Size of Specimens. 76. The hardness tests shall be made on nominal 2 by 2 by 6-in. specimens. The actual cross-section dimensions and length shall be measured.

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[1] See Fig. 8 of the Appendix for a sample compression-perpendicular-to-grain data sheet form. Fig. 9 of the Appendix shows a sample computation data card.

Method of Test.

77. The modified ball test with a "ball" 0.444 in. in diameter shall be used for determining hardness. (See Fig. 12.) The load at which the "ball" has penetrated to one-half its diameter as indicated by the tightening of the collar against the specimen, shall be observed.

Number of Penetrations.

78. Two penetrations shall be made on a tangential surface, two on a radial surface, and two on each end. The choice between the two radial and between the two tangential surfaces shall be such as to give a fair average of the piece. The penetrations shall be far enough from the edge to prevent splitting or chipping.[1]

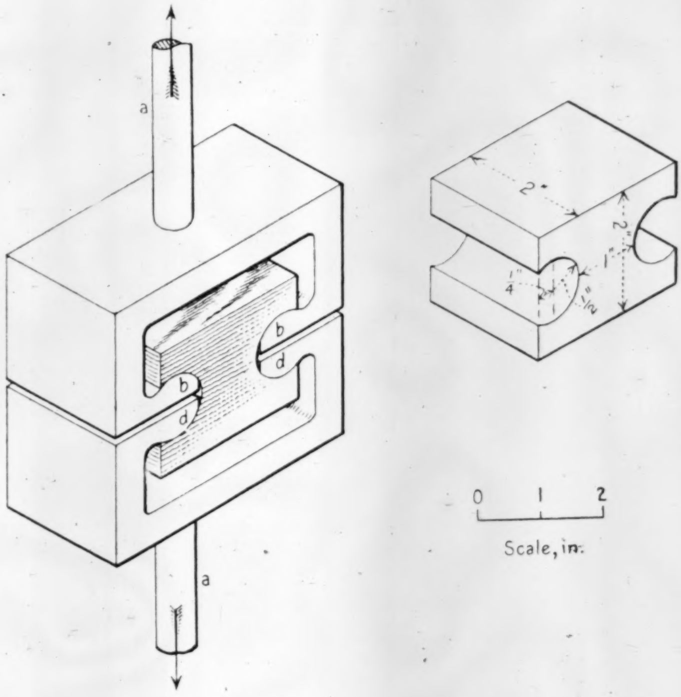


FIG. 14.—Diagrammatic Sketch of Method of Conducting Tension-Perpendicular-to-Grain Test, with Details of Test Specimen.

Rate of Application of Load.

79. The load shall be applied continuously throughout the test at a rate of 0.25 in. per minute.

Weight and Moisture Content.

80. The specimen shall be weighed after test and a moisture section 1 in. in length shall be cut.

---

[1] See Fig. 10 of the Appendix for a sample data and computation card.

(*F*) *Shear Parallel to Grain.*

Size of Specimens. 81. The shear-parallel-to-grain tests shall be made on nominal 2 by 2 by 2½-in. specimens notched as illustrated in Fig. 13 to produce failure on a 2 by 2-in. surface. The actual dimensions of the shearing surface shall be measured.

Method of Test. 82. A shear tool similar to that illustrated in Fig. 13, providing a ⅛-in. offset between the inner edge of the supporting surface and the plane along which the failure occurs, shall be used. The load shall be applied and the specimen supported on end-grain surfaces. Care shall be taken in placing the specimen in the shear tool to see that the cross bar is adjusted so that the edges of the specimen are vertical and the end rests evenly on the support over the contact area. The maximum load only will be observed.

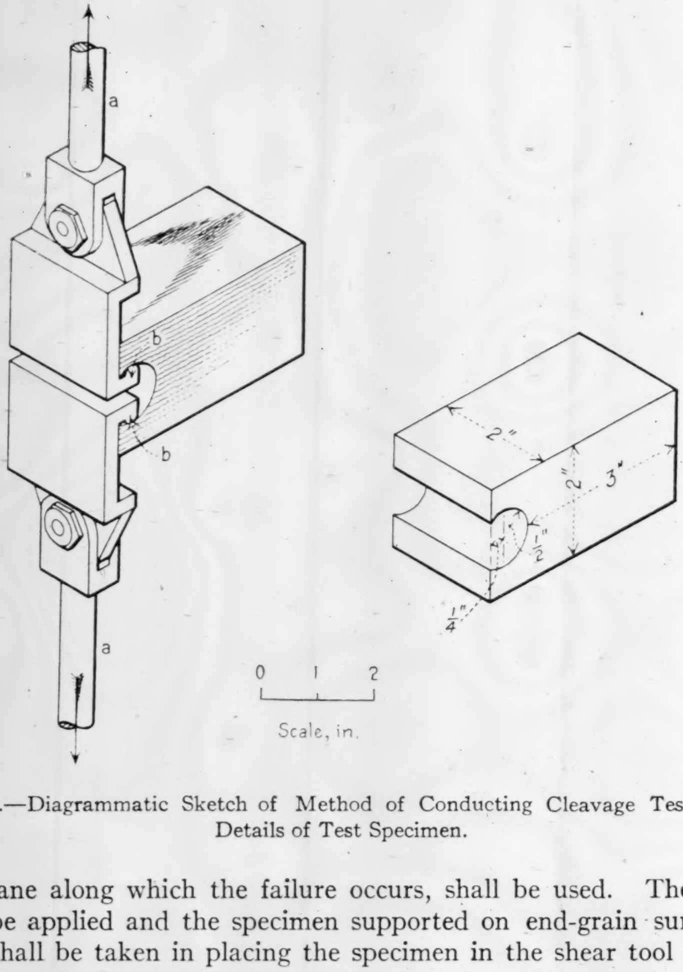


FIG. 15.—Diagrammatic Sketch of Method of Conducting Cleavage Test, with Details of Test Specimen.

Rate of Application of Load. 83. The load shall be applied continuously throughout the test at a rate of 0.015 in. per minute.

Test Failures. 84. The failure shall be sketched on the data card.[1] In all cases where the failure at the base of the specimen extends back onto the supporting surface, the test shall be culled.

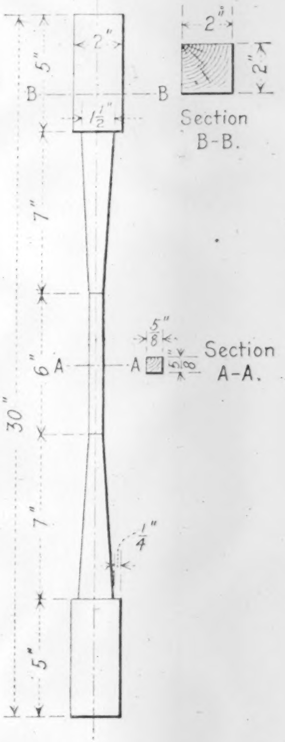


FIG. 16.—Details of Tension-Parallel-to-Grain Test Specimen.

Moisture Content. 85. The portion of the test piece which is sheared off shall be used as a moisture section.

(G) *Tension Perpendicular to Grain.*

Size of Specimens. 86. The tension-perpendicular-to-grain tests shall be made on specimens of the nominal size and shape shown in Fig. 14. The actual width and length at minimum sections shall be measured.

---

[1] See Fig. 11 of the Appendix for a sample tangential-shear data sheet form.

Method of Test. 87. The specimens shall be held during test in grips as shown in Fig. 14. The maximum load only shall be observed.

Rate of Application of Load. 88. The load shall be applied continuously throughout the test at a rate of 0.25 in. per minute.

Sketch of Failure. 89. The failure shall be sketched on the data card.[1]

Moisture Content. 90. One of the pieces remaining after failure, or a section split along the surface of failure, shall be used as a moisture specimen.

(*H*) *Cleavage.*

Size of Specimens. 91. The cleavage tests shall be made on specimens of the form and size shown in Fig. 15. The actual width and length at minimum section shall be measured.

Method of Test. 92. The specimens shall be held during test in grips as shown in Fig. 15. The maximum load only shall be observed.

Rate of Operation. 93. The load shall be applied continuously throughout the test at a rate of 0.25 in. per minute.

Sketch of Failure. 94. The failure shall be sketched on the data card.[2]

Moisture Content. 95. One of the pieces remaining after failure, or a section split along the surface of failure, shall be used as a moisture specimen.

(*I*) *Tension Parallel to Grain.*

Size of Specimens. 96. The tension-parallel-to-grain tests shall be made on specimens of the size and shape shown in Fig. 16. The actual cross-section dimensions at minimum section shall be measured.

Method of Test. 97. The specimen shall be held during test by plates notched to fit around the test piece and under the 0.25-in. shoulder provided for that purpose. A spherical bearing shall be used on at least one end of the specimen. Maximum load only will be observed.

Rate of Application of Load. 98. The load shall be applied continuously throughout the test at a rate of 0.05 in. per minute.

Sketch of Failure. 99. The failure shall be sketched on the data sheet.[3]

Moisture Content. 100. A moisture section about 3 in. in length shall be cut from the minimum section near the failure.

(*J*) *Specific Gravity and Shrinkage in Volume.*

Size of Specimens. 101 The specific gravity and shrinkage in volume tests shall be made on nominal 2 by 2 by 6-in. specimens. The actual cross-section dimensions and length shall be measured.

---

[1] See Fig. 12 of the Appendix for a sample radial-tension-perpendicular-to-grain data sheet form.

[2] See Fig. 13 of the Appendix for a sample radial-cleavage data sheet form.

[3] See Fig. 14 of the Appendix for a sample tension-parallel-to-grain data sheet form.

Determination Method.

102. (*a*) Both specific gravity and shrinkage-in-volume determinations shall be obtained on the same specimen.

(*b*) A carbon impression of the end of the green specimen shall be made on the back of the data card.[1] In like manner, a carbon impression of the same end shall be made after the specimen has been oven dried. (See Paragraph *e*.)

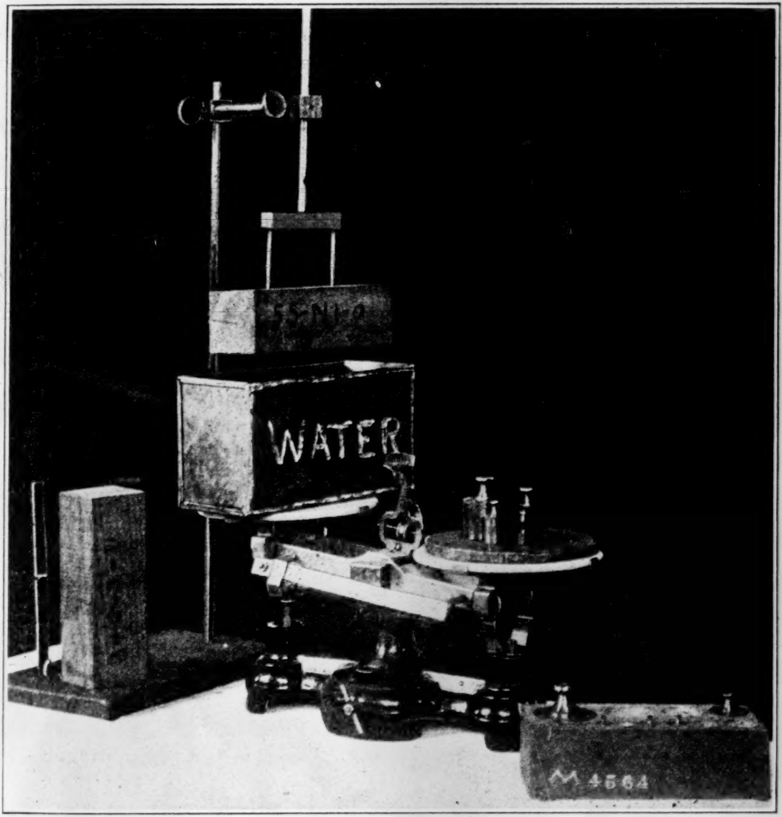


FIG. 17.—Method of Conducting Specific Gravity and Shrinkage-in-Volume Test.

(*c*) The specimen shall be weighed when green and the volume shall be determined by the immersion method.

(*d*) The green specimens after immersion shall be open-piled and allowed to air season under room conditions until approximately constant weight is attained.

---

[1] See Fig. 15 of the Appendix for a sample specific gravity and shrinkage-in-volume data card form.

(*e*) The specimens shall then be open-piled in an oven and dried at 100° C. until constant weight is reached.

(*f*) After oven drying, the specimens shall be weighed, and while still warm shall be immersed in a hot paraffin bath, care being taken to remove them quickly to insure a thin coating.

(*g*) The volume of the paraffin-coated specimen shall be determined by immersion as before.

(*h*) Fig. 17 illustrates the apparatus used in determining the specific gravity and shrinkage in volume.

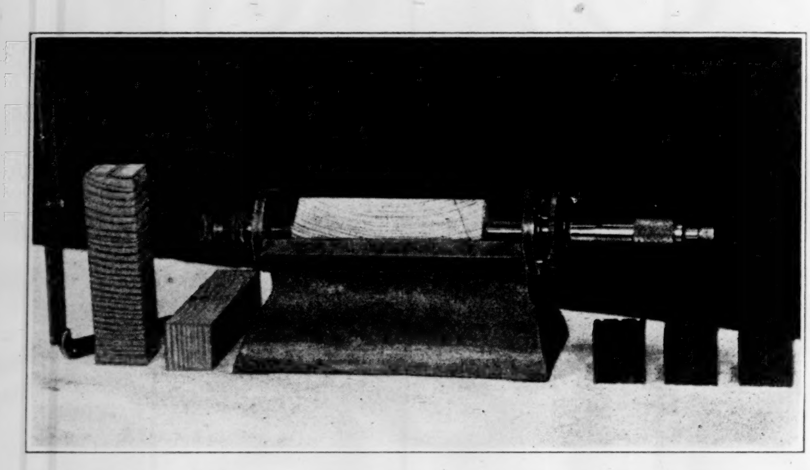


FIG. 18.—Method of Measuring Radial and Tangential Shrinkage.

(*K*) *Radial and Tangential Shrinkage.*

Size of Specimen. 103. The radial and tangential-shrinkage determinations shall be made on nominal 1 by 4 by 1-in. specimens. The specimen shall be measured across the (4-in.) dimension in which the shrinkage is to be determined.

Weight. 104. The specimen shall be weighed when green and after subsequent oven drying.

Drying. 105. (*a*) The green specimens shall be open-piled and allowed to air season under room conditions until approximately constant weight is attained.

(*b*) The specimens shall then be open-piled in an oven and dried at 100° C. until constant weight is attained.

Final Measurement. 106. Final measurement shall be made on the oven-dry specimen.[1]

---

[1] See Fig. 16 of the Appendix for a sample radial and tangential-shrinkage data card form.

107. Fig. 18 illustrates the method of making the radial and tangential-shrinkage measurements. An ordinary micrometer of required accuracy is suitable for this work.

(*L*) *Moisture Determination.*

Selection. 108. The sample for moisture determinations of each test specimen shall be selected as heretofore described for each test.

Weighing. 109. Immediately after obtaining the moisture sample, all loose splinters shall be removed and the sample shall be weighed.

Drying. 110. The moisture samples shall be open-piled in an oven and dried at a temperature of 100° C. until constant weight is attained, after which the oven-dry weight shall be determined.

Moisture Content. 111. The loss in weight expressed in percentage of the oven-dry weight as above determined shall be considered the moisture content of the specimen.

VI. TOLERANCES.

(*A*) *Weights.*

Weights. 112. The weight of test specimens and of moisture samples shall be determined to an accuracy of not less than 0.2 per cent.

(*B*) *Measurements.*

Measurements. 113. Measurements of test specimens will be made to the nearest 0.01 in. except in the case of tension parallel to grain, radial shrinkage, and tangential shrinkage, when measurements will be taken to the nearest 0.001 in.

(*C*) *Testing Machine Speeds.*

Testing Machine Speeds. 114. In no case shall the testing machine speed used vary more than 25 per cent from that specified for a given test. The load shall be applied continuously, without interruption, at the required speed throughout the test.

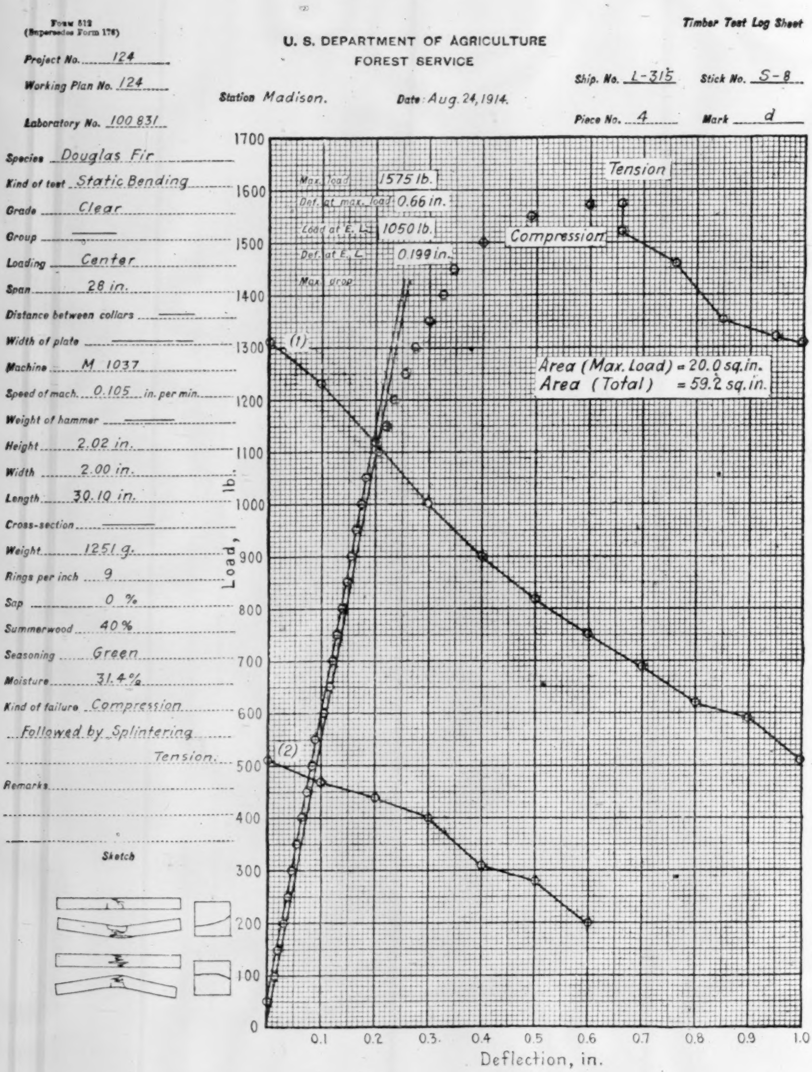
VII. CALIBRATION.

Calibration. 115. All apparatus used in obtaining data shall be calibrated at sufficiently frequent intervals to insure accuracy.[1]

---

[1] The Society has adopted Standard Methods of Verification of Testing Machines (Serial Designation: E 4), 1924 Book of A.S.T.M. Standards.

APPENDIX.



Form 512
(Supersedes Form 176)

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Timber Test Log Sheet

Project No. 124
Working Plan No. 124
Laboratory No. 100 831
Station Madison.
Date: Aug. 24, 1914.
Ship. No. L-315
Stick No. S-8
Piece No. 4
Mark d

Species Douglas Fir
Kind of test Static Bending
Grade Clear
Group ——
Loading Center
Span 28 in.
Distance between collars ——
Width of plate ——
Machine M 1037
Speed of mach. 0.105 in. per min.
Weight of hammer ——
Height 2.02 in.
Width 2.00 in.
Length 30.10 in.
Cross-section ——
Weight 1251 g.
Rings per inch 9
Sap 0 %
Summerwood 40 %
Seasoning Green
Moisture 31.4 %
Kind of failure Compression Followed by Splintering Tension.
Remarks

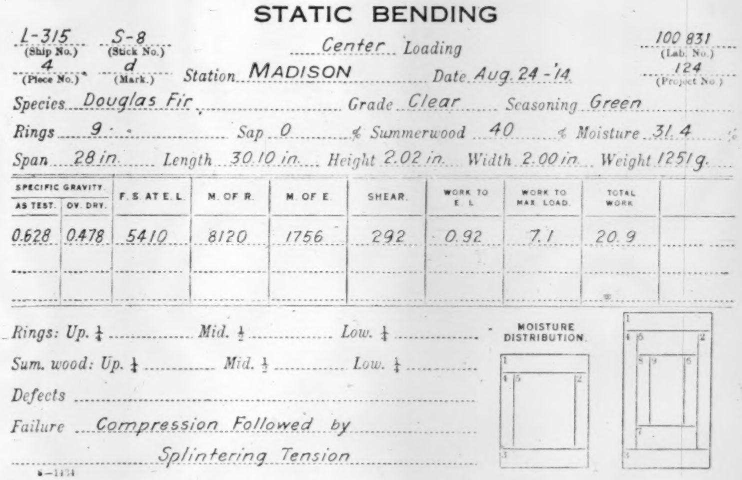
Sketch

Max. load 1575 lb.
Def. at max. load 0.66 in.
Load at E. L. 1050 lb.
Def. at E. L. 0.199 in.
Max. drop

Area (Max. Load) = 20.0 sq. in.
Area (Total) = 59.2 sq. in.

Load, lb.
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Deflection, in.
(1)
(2)
Tension
Compression

FIG. 1.—Sample Data Sheet for Static Bending Test.



STATIC BENDING

L-315 (Ship No.) S-8 (Stick No.) Center Loading 100 831 (Lab. No.)

4 (Piece No.) d (Mark.) Station MADISON Date Aug. 24 - '14 124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

Rings 9 Sap 0 % Summerwood 40 % Moisture 31.4 %

Span 28 in. Length 30.10 in. Height 2.02 in. Width 2.00 in. Weight 1251 g.

SPECIFIC GRAVITY		F. S. AT E. L.	M. OF R.	M. OF E.	SHEAR.	WORK TO E. L.	WORK TO MAX. LOAD.	TOTAL WORK	
AS TEST.	OV. DRY.								
0.628	0.478	5410	8120	1756	292	0.92	7.1	20.9	

Rings: Up. ¼ Mid. ½ Low. ¼

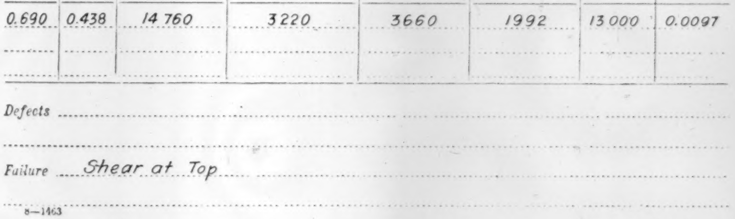
Sum. wood: Up. ¼ Mid. ½ Low. ¼

Defects

Failure Compression Followed by Splintering Tension

8—1434

FIG. 2.—Sample Computation Data Card for Static Bending Test.



COMPRESSION PARALLEL TO GRAIN

L-315 (Ship. No.) E-11 (Stick No.) 101 101 (Lab. No.)

1 (Piece No.) d-1 (Mark) Station Madison Date Aug. 25, 1914 124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

Rings 9 Sap 90 % Summerwood 38 % Moisture 57.6 %

Length 8.00 in. Cross section 2.01 in. X 2.01 in. Weight 365 g.

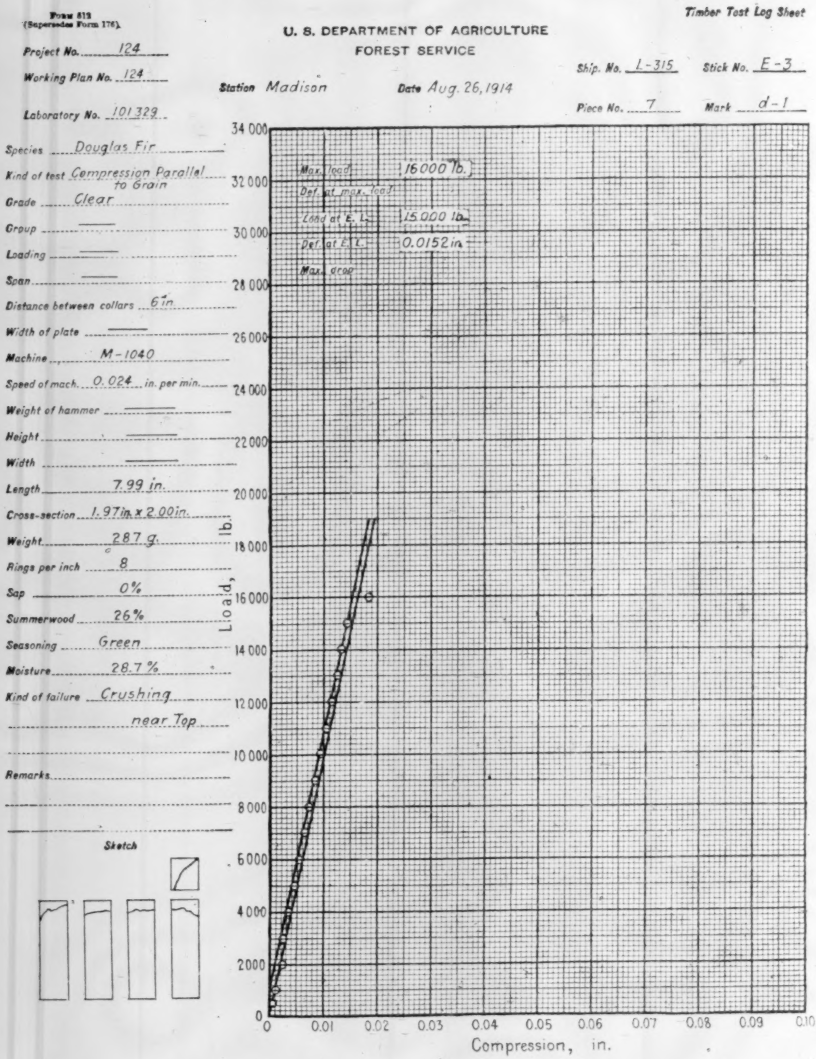
SPECIFIC GRAVITY		MAX. LOAD	CRUSH. ST. AT E. L.	MAX. CRUSH. ST.	M. OF E.	LOAD AT E. L.	DEF. AT E. L.
At Test	Ov. Dry						
0.690	0.438	14 760	3220	3660	1992	13 000	0.0097

Defects

Failure Shear at Top

8—1463

FIG. 3.—Sample Computation Data Card for Compression-Parallel-to-Grain Test.



Form 812
(Supersedes Form 176)

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Timber Test Log Sheet

Project No. 124
Working Plan No. 124
Laboratory No. 101329
Station Madison
Date Aug. 26, 1914
Ship. No. L-315
Stick No. E-3
Piece No. 7
Mark d-1

Species Douglas Fir
Kind of test Compression Parallel to Grain
Grade Clear
Group ——
Loading ——
Span ——
Distance between collars 6 in.
Width of plate ——
Machine M-1040
Speed of mach. 0.024 in. per min.
Weight of hammer ——
Height ——
Width ——
Length 7.99 in.
Cross-section 1.97 in. x 2.00 in.
Weight 287 g.
Rings per inch 8
Sap 0%
Summerwood 26%
Seasoning Green
Moisture 28.7 %
Kind of failure Crushing near Top
Remarks

Max. load 16000 lb.
Def. at max. load
Load at E. L. 15000 lb.
Def. at E. L. 0.0152 in.
Max. drop

Sketch
Load, lb.
34 000
32 000
30 000
28 000
26 000
24 000
22 000
20 000
18 000
16 000
14 000
12 000
10 000
8000
6000
4000
2000
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
Compression, in.

FIG. 4.—Sample Data Sheet for Compression-Parallel-to-Grain Test.

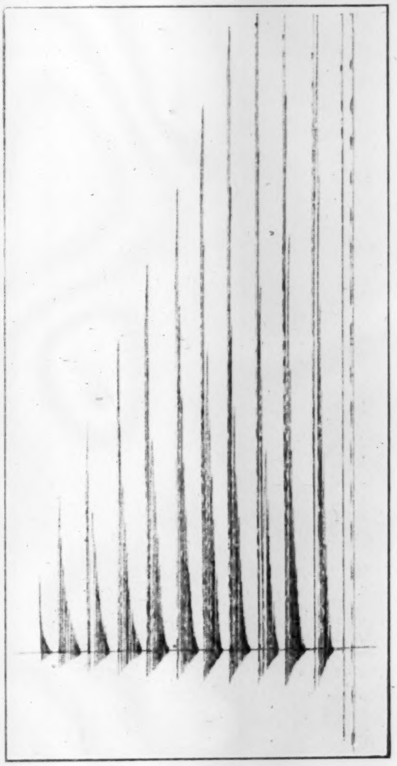
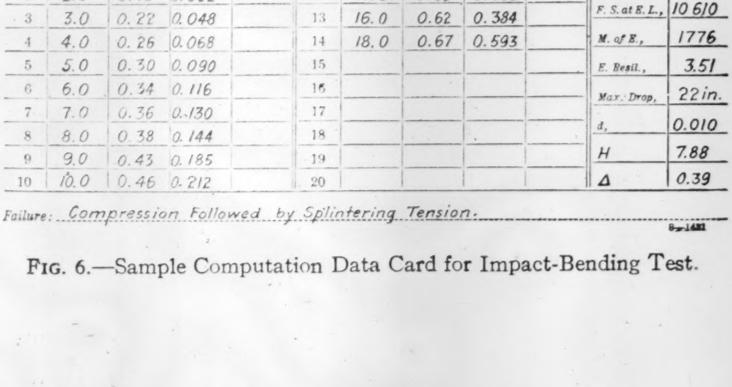


FIG. 5.—Sample Drum Record of Impact Test.



L-315 (Ship. No.)
E-12 (Stick No.)
1 (Piece No.)
C (Mark)

IMPACT BENDING

Station MADISON Date Aug. 20, 1914

101 151 (Lab. No.)
124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

Rings 8 Sap 100 % Summerwood 30 % Moisture 61.4 %

Hammer 50 lbs. Span 28 in. Length 29.94 in. Height 2.00 in. Width 2.00 in. Weight 1370 g.

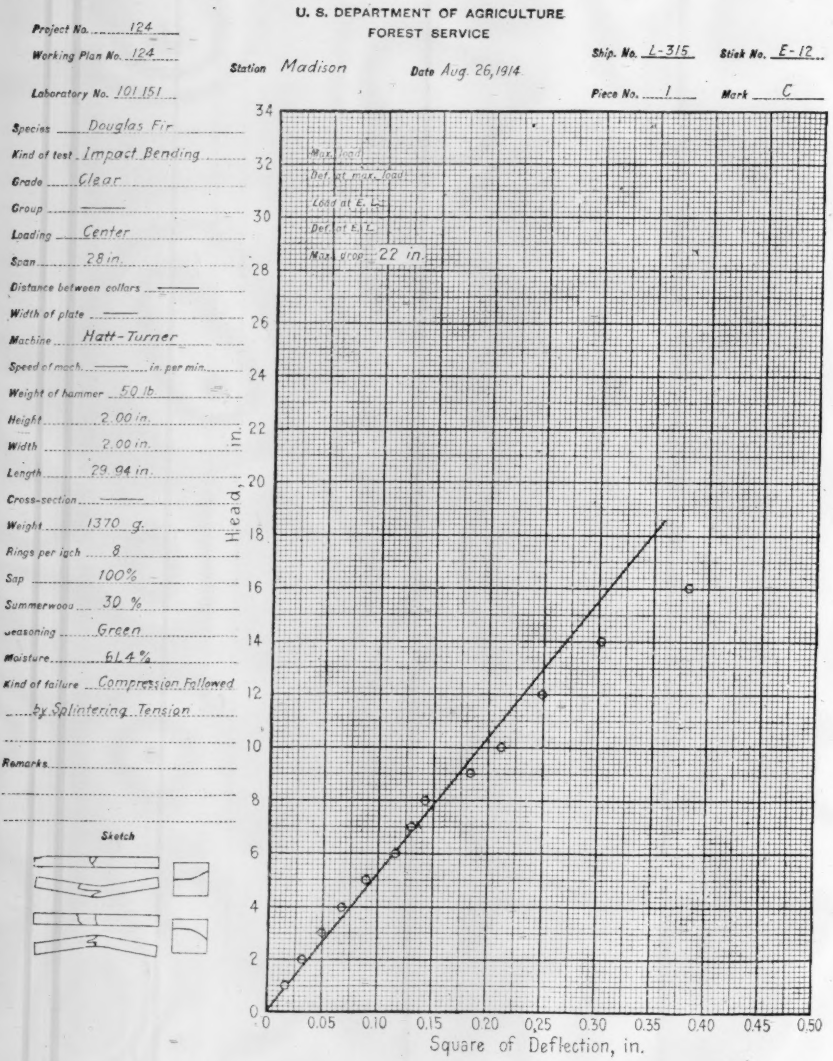
Drop No.	Head.	Def.	$(Def.+d)^2$.	Set.	Drop No.	Head.	Def.	$(Def.+d)^2$.	Set.
1	1.0	0.13	0.017		11	12.0	0.50	0.250	
2	2.0	0.18	0.032		12	14.0.	0.55	0.302	
3	3.0	0.22	0.048		13	16.0	0.62	0.384	
4	4.0	0.26	0.068		14	18.0	0.67	0.593	
5	5.0	0.30	0.090		15				
6	6.0	0.34	0.116		16				
7	7.0	0.36	0.130		17				
8	8.0	0.38	0.144		18				
9	9.0	0.43	0.185		19				
10	10.0	0.46	0.212		20				

Sp. Gr. (at test),	0.698
Sp. Gr. (oven dry),	0.432
F. S. at E. L.,	10 610
M. of E.,	1776
E. Resil.,	3.51
Max. Drop,	22 in.
d,	0.010
H	7.88
Δ	0.39

Failure: Compression Followed by Splintering Tension.

8-1431

FIG. 6.—Sample Computation Data Card for Impact-Bending Test.



U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Project No. 124
Working Plan No. 124
Laboratory No. 101 151
Station Madison
Date Aug. 26, 1914
Ship. No. L-315
Stick No. E-12
Piece No. 1
Mark C

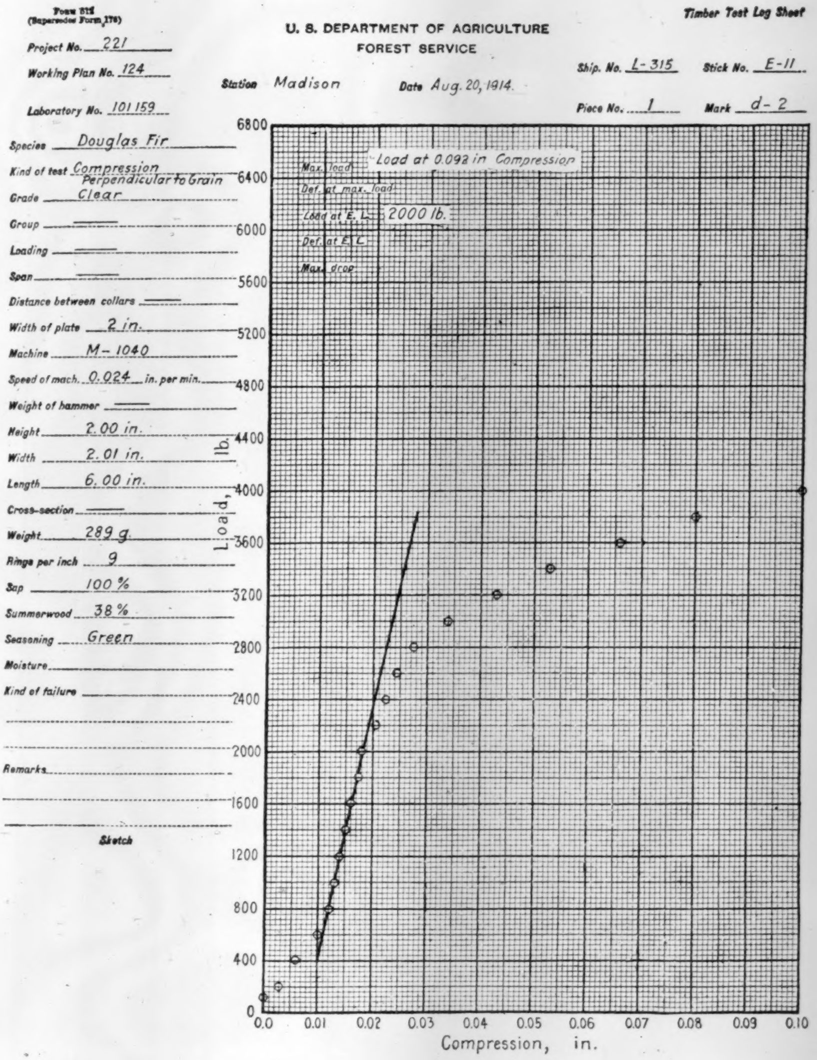
Species Douglas Fir
Kind of test Impact Bending
Grade Clear
Group ——
Loading Center
Span 28 in.
Distance between collars ——
Width of plate ——
Machine Hatt-Turner
Speed of mach. —— in. per min.
Weight of hammer 50 lb.
Height 2.00 in.
Width 2.00 in.
Length 29.94 in.
Cross-section ——
Weight 1370 g.
Rings per inch 8
Sap 100%
Summerwood 30 %
Seasoning Green
Moisture 61.4%
Kind of failure Compression Followed by Splintering Tension
Remarks

Sketch

Max. load
Def. at max. load
Load at E. L.
Def. at E. L.
Max. drop 22 in.

34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Head, in.
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Square of Deflection, in.

FIG. 7.—Sample Data Sheet for Impact-Bending Test.



Form 312
(Supersedes Form 178)

Timber Test Log Sheet

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Project No. 221

Working Plan No. 124

Station Madison

Date Aug. 20, 1914.

Ship. No. L-315

Stick No. E-11

Laboratory No. 101 159

Piece No. 1

Mark d-2

Species Douglas Fir

Kind of test Compression Perpendicular to Grain

Grade Clear

Group ——

Loading ——

Span ——

Distance between collars ——

Width of plate 2 in.

Machine M-1040

Speed of mach. 0.024 in. per min.

Weight of hammer ——

Height 2.00 in.

Width 2.01 in.

Length 6.00 in.

Cross-section ——

Weight 289 g.

Rings per inch 9

Sap 100 %

Summerwood 38 %

Seasoning Green

Moisture

Kind of failure

Remarks

Sketch

Max. load Load at 0.092 in Compression

Def. at max. load

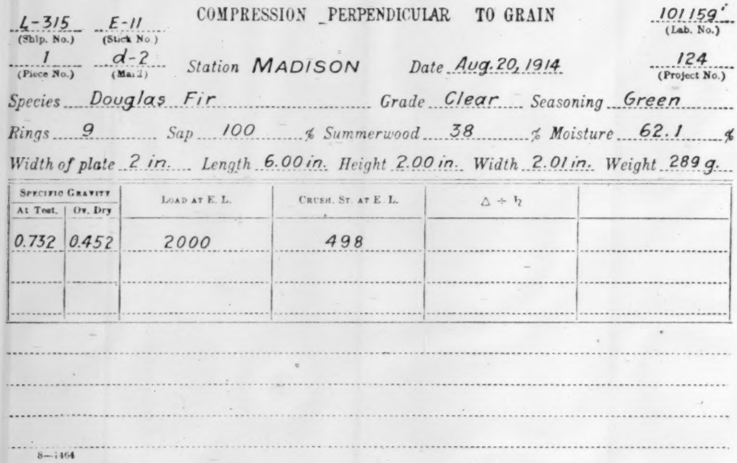
Load at E. L. 2000 lb.

Def. at E. L.

Max. drop

6800
6400
6000
5600
5200
4800
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
Load, lb.
0.0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
Compression, in.

FIG. 8.—Sample Data Sheet for Compression-Perpendicular-to-Grain Test.



L-315 (Ship. No.) E-11 (Stick No.) COMPRESSION PERPENDICULAR TO GRAIN 101159' (Lab. No.)

1 (Piece No.) d-2 (Mark.) Station MADISON Date Aug. 20, 1914 124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

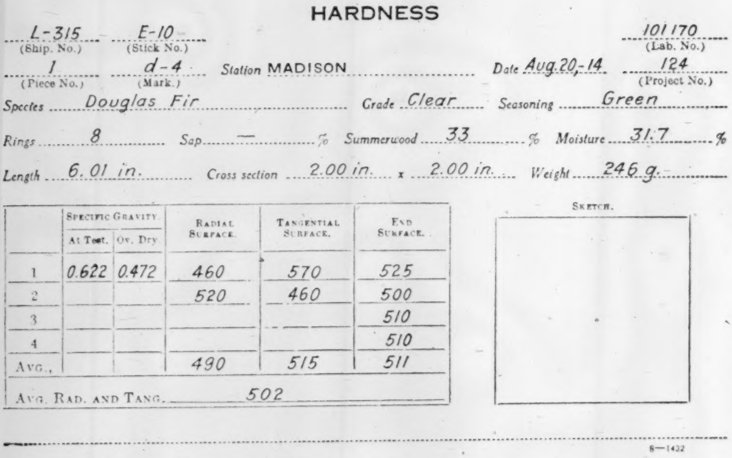
Rings 9 Sap 100 % Summerwood 38 % Moisture 62.1 %

Width of plate 2 in. Length 6.00 in. Height 2.00 in. Width 2.01 in. Weight 289 g.

SPECIFIC GRAVITY		LOAD AT E. L.	CRUSH. ST. AT E. L.	Δ ÷ h	
At Test.	Ov. Dry				
0.732	0.452	2000	498		

8—1464

FIG. 9.—Sample Computation Data Card for Compression-Perpendicular-to-Grain Test.



HARDNESS

L-315 (Ship. No.) E-10 (Stick No.) 101170 (Lab. No.)

1 (Piece No.) d-4 (Mark.) Station MADISON Date Aug. 20,-14 124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

Rings 8 Sap — % Summerwood 33 % Moisture 31.7 %

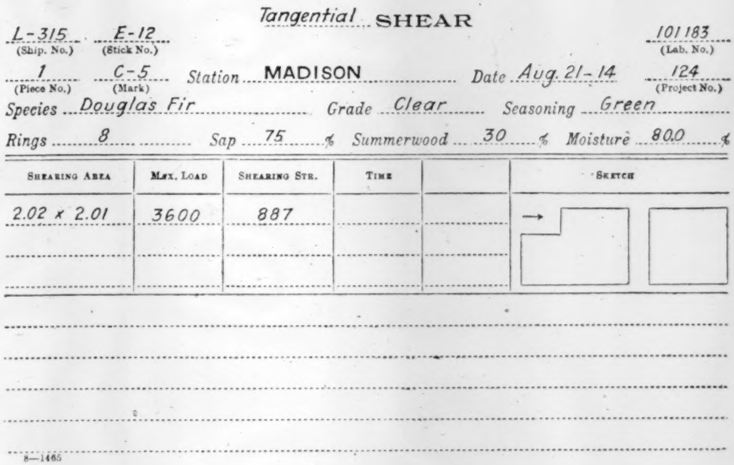
Length 6.01 in. Cross section 2.00 in. x 2.00 in. Weight 246 g.

	SPECIFIC GRAVITY		RADIAL SURFACE.	TANGENTIAL SURFACE.	END SURFACE.
	At Test.	Ov. Dry			
1	0.622	0.472	460	570	525
2			520	460	500
3					510
4					510
AVG.,			490	515	511
AVG. RAD. AND TANG.			502		

SKETCH.

8—1432

FIG. 10.—Sample Data and Computation Card for Hardness Test.



Tangential SHEAR

L-315 (Ship. No.) E-12 (Stick No.) 101 183 (Lab. No.)

1 (Piece No.) C-5 (Mark) Station MADISON Date Aug. 21-14 124 (Project No.)

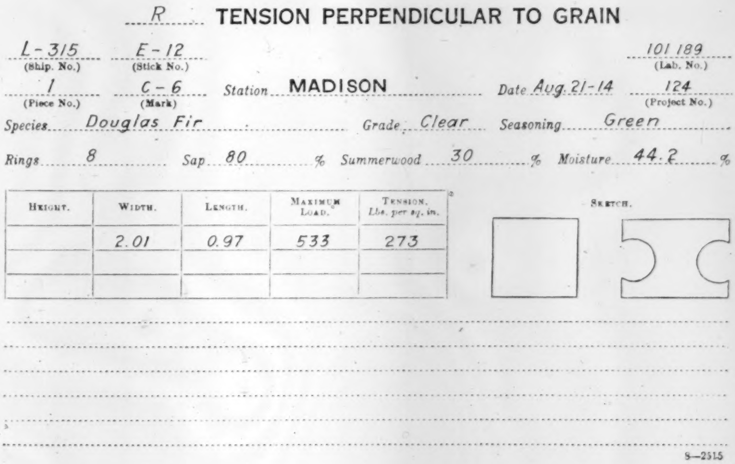
Species Douglas Fir Grade Clear Seasoning Green

Rings 8 Sap 75 % Summerwood 30 % Moisture 80.0 %

SHEARING AREA	MAX. LOAD	SHEARING STR.	TIME		SKETCH
2.02 x 2.01	3600	887			

8—1465

FIG. 11.—Sample Data and Computation Card for Tangential-Shear-Parallel-to-Grain Test. (Surface of failure tangential.)



R TENSION PERPENDICULAR TO GRAIN

L-315 (Ship. No.) E-12 (Stick No.) 101 189 (Lab. No.)

1 (Piece No.) C-6 (Mark) Station MADISON Date Aug. 21-14 124 (Project No.)

Species Douglas Fir Grade Clear Seasoning Green

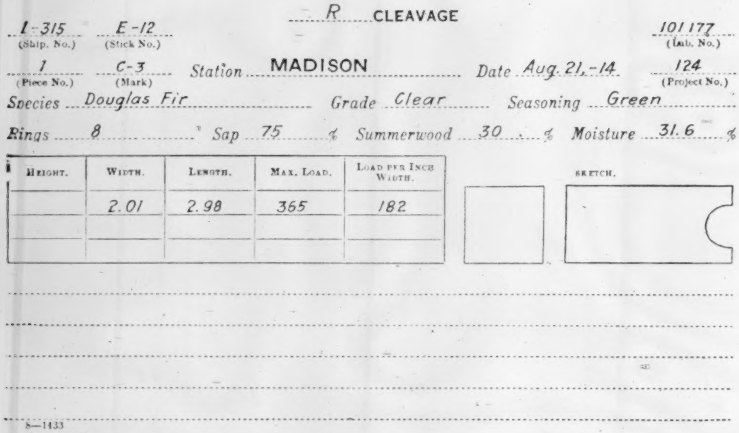
Rings 8 Sap 80 % Summerwood 30 % Moisture 44.2 %

HEIGHT.	WIDTH.	LENGTH.	MAXIMUM LOAD.	TENSION. Lbs. per sq. in.
	2.01	0.97	533	273

SKETCH.

8—2515

FIG. 12.—Sample Data and Computation Card for Radial-Tension-Perpendicular-to-Grain Test. (Surface of failure radial.)



R CLEAVAGE

1-315 (Ship. No.) E-12 (Stick No.) 101177 (Lab. No.)

1 (Piece No.) C-3 (Mark) Station MADISON Date Aug. 21,-14 124 (Project No.)

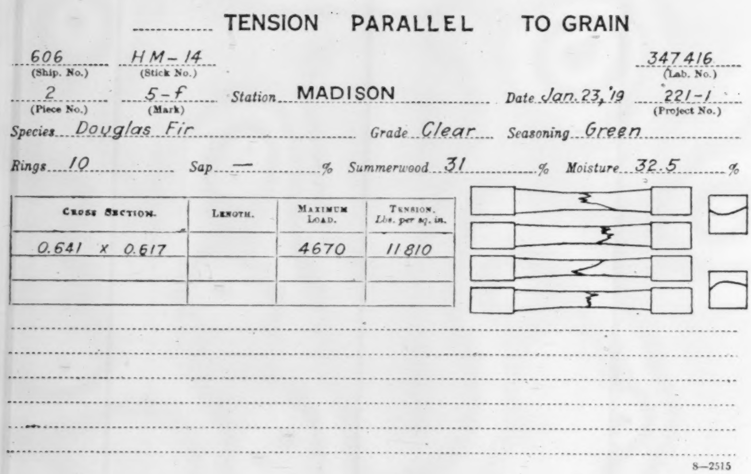
Species Douglas Fir Grade Clear Seasoning Green

Rings 8 Sap 75 % Summerwood 30 % Moisture 31.6 %

HEIGHT.	WIDTH.	LENGTH.	MAX. LOAD.	LOAD PER INCH WIDTH.
	2.01	2.98	365	182

8—1433

FIG. 13.—Sample Data and Computation Card for Radial-Cleavage Test. (Surface of failure radial.)



TENSION PARALLEL TO GRAIN

606 (Ship. No.) HM-14 (Stick No.) 347416 (Lab. No.)

2 (Piece No.) 5-f (Mark) Station MADISON Date Jan. 23, '19 221-1 (Project No.)

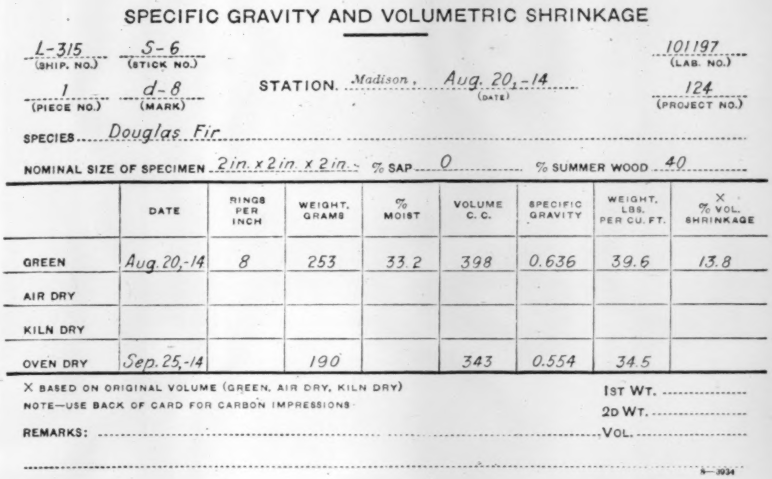
Species Douglas Fir Grade Clear Seasoning Green

Rings 10 Sap — % Summerwood 31 % Moisture 32.5 %

CROSS SECTION.	LENGTH.	MAXIMUM LOAD.	TENSION. Lbs. per sq. in.
0.641 x 0.617		4670	11810

8—2515

Fig. 14.—Sample Data and Computation Card for Tension-Parallel-to-Grain Test.



SPECIFIC GRAVITY AND VOLUMETRIC SHRINKAGE

L-315 (SHIP. NO.) S-6 (STICK NO.) 101197 (LAB. NO.)

1 (PIECE NO.) d-8 (MARK) STATION. Madison, Aug. 20,-14 (DATE) 124 (PROJECT NO.)

SPECIES Douglas Fir

NOMINAL SIZE OF SPECIMEN 2in. x 2in. x 2in. % SAP 0 % SUMMER WOOD 40

	DATE	RINGS PER INCH	WEIGHT, GRAMS	% MOIST	VOLUME C. C.	SPECIFIC GRAVITY	WEIGHT, LBS. PER CU. FT.	X % VOL. SHRINKAGE
GREEN	Aug. 20,-14	8	253	33.2	398	0.636	39.6	13.8
AIR DRY								
KILN DRY								
OVEN DRY	Sep. 25,-14		190		343	0.554	34.5	

X BASED ON ORIGINAL VOLUME (GREEN, AIR DRY, KILN DRY)

NOTE—USE BACK OF CARD FOR CARBON IMPRESSIONS

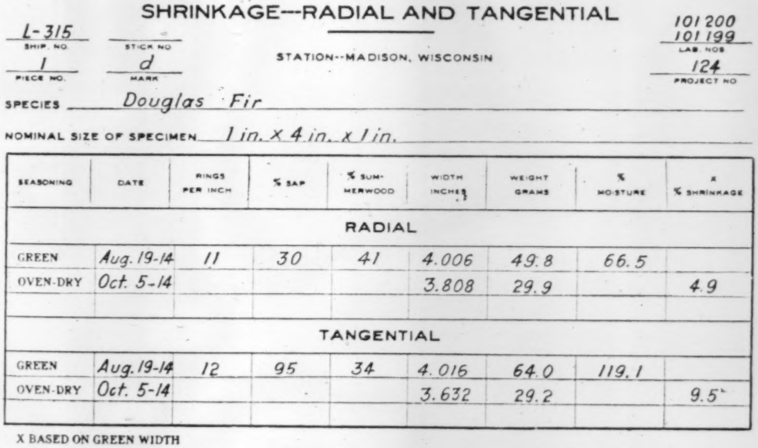
1ST WT.

2D WT.

REMARKS: VOL.

8—3934

FIG. 15.—Sample Data and Computation Card for Specific Gravity and Shrinkage-in-Volume Test.



SHRINKAGE—RADIAL AND TANGENTIAL

L-315 SHIP. NO. STICK NO. 101200 101199 LAB. NOS

1 PIECE NO. d MARK STATION--MADISON, WISCONSIN 124 PROJECT NO

SPECIES Douglas Fir

NOMINAL SIZE OF SPECIMEN 1 in. x 4 in. x 1 in.

SEASONING	DATE	RINGS PER INCH	% SAP	% SUMMERWOOD	WIDTH INCHES	WEIGHT GRAMS	% MOISTURE	X % SHRINKAGE
RADIAL								
GREEN	Aug. 19-14	11	30	41	4.006	49.8	66.5	
OVEN-DRY	Oct. 5-14				3.808	29.9		4.9
TANGENTIAL								
GREEN	Aug. 19-14	12	95	34	4.016	64.0	119.1	
OVEN-DRY	Oct. 5-14				3.632	29.2		9.5

X BASED ON GREEN WIDTH

FIG. 16.—Sample Data and Computation Card for Radial and Tangential-Shrinkage Tests.

TENTATIVE METHODS FOR CONDUCTING STATIC TESTS OF TIMBERS IN STRUCTURAL SIZES[1]

Serial Designation: D 198 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Although numerous tests of timber in structural sizes have been made for various purposes, there has been a general lack of uniformity of test procedure. Consequently, it has not been possible to correlate data from different sources, nor have the results obtained by different investigators contributed their full measure of usefulness toward an increasing fund of knowledge. Study and experience have shown the extent to which various factors, such as loading appliances, rate of loading, etc., influence test results, and it is with the thought of standardizing these and other factors that this test procedure is prepared. The plan has been to cover very definitely the tests of certain types of timbers such as bridge stringers and joists and at the same time to suggest procedure, so far as possible, for other structural timber forms. Summarized, the underlying purpose is the establishment of practice which will afford uniform results of the greatest ultimate value from all tests of timbers and at the same time permit the correlation of data so far as possible with existing data on timbers of certain species.

It is not the intention to discourage the use of methods other than those herein prescribed whenever the testing problem is of such nature as to warrant their application. However, experience has emphasized the importance of the requirements that have been specified in these methods, and variations in apparently minor details will often seriously affect the data obtained. It is recommended that any variations from the methods herein prescribed shall be recorded.

The field of timber testing is so broad, and involves so many objectives, particularly when built-up or manufactured articles are considered, that it is obviously difficult, if not impossible, to formulate correct procedure for all such cases. Ample opportunity, therefore, still awaits the application of initiative to special testing problems and promotion of progress in the art. It is hoped, however, that the principles incorporated in the proposed methods will at least serve to some extent as a guide in tests of even a special nature.

The test methods presented are the outgrowth of years of experience and research, largely on the part of the United States Forest Service. Such sample data forms are included as were thought helpful to investigators in

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, Forest Products Laboratory, Madison, Wis.

systematizing records. No attempt has been made to cover methods of computation or analysis, as these were considered to lie outside the scope of the standard. Data properly recorded can be analyzed at will, but fundamental differences in test procedure present a barrier beyond which analysis and correlation of results cannot proceed with any degree of assurance.

Purpose of Tests.

1. Tests of timbers in structural sizes are made to afford:

(*a*) Data upon which to base the formulation of grading rules and specifications.

(*b*) Data upon which to establish the relation between the strength properties of structural timbers and of small clear specimens cut from them, and for use in the establishment of allowable stresses.

(*c*) Data as to the influence of defects on the mechanical properties of timbers.

(*d*) Data on the strength properties of different species in structural sizes.

(*e*) Data for use in checking existing formulas relating to structural timbers.

(*f*) Data as to the influence of seasoning on the mechanical properties.

(*g*) Data as to the effect of form and shape of specimen on the properties.

(*h*) Data as to the influence of preservatives and methods of preservative treatment on the mechanical properties.

Classes of Tests.

2. In general, tests of timbers are divided into two classes, as follows:

(*a*) Major tests, that is, tests of principal members under investigation.

(*b*) Minor tests, that is, tests of small clear specimens cut from the principal members.

Kind of Tests.

3. (*a*) The principal tests of such structural timbers as bridge stringers or joists are: Static bending, compression parallel to grain, and compression perpendicular to grain.

(*b*) The accompanying minor tests on small clear specimens are: Static bending, compression parallel to grain, compression perpendicular to grain, hardness, and shear parallel to grain.

MATERIAL

I. COLLECTION

(*A*) *Selection*

Authentic Identification.

4. The material for test shall be selected by one qualified to identify the species.

Procedure for Bridge Stringers, Joists, etc.

5. In any given case, the number of test specimens shall be determined from due consideration of the purpose in mind, since definite instructions cannot be given to cover all cases. The following procedure applies particularly to full-size timbers, such as bridge stringers and joists, and incidentally to other types, as fabricated beams, to which special reference will be made in small-type paragraphs.

Number and Size of Major Specimens.

6. (*a*) For tests of timbers of any given species in structural sizes, such as bridge stringers, requiring a range in grade of material, at least forty 32-ft. or eighty 16-ft. green unsurfaced timbers should be selected in a manner that will provide representative material. The length of specimens required for test is dependent upon the depth. For suggested lengths of timbers other than bridge stringers, see Section 22.

(*b*) Timbers 8 by 16 in. or 6 by 12 in. in nominal cross-section are especially recommended.

Selection and Matching of Specimens.

7. Each 32-ft. timber shall be cut in half to furnish one 16-ft. specimen to be tested green and one to be tested air-dry, thus affording end matching. Where only 16-ft. material is available, the timbers shall be selected and matched in pairs, one timber to be tested green and the other to be tested air-dry. In matching these 16-ft. timbers all factors influencing their strength should, so far as practicable, be considered. Some of the most important factors are density, rate of growth, direction of grain (straight, diagonal, or spiral), character and location of defects (such as knots, checks, etc.), position of specimen in tree with respect to cross-section or height, and the characteristics of individual trees.

(*B*) *Field Marking*

Butt Designation.

8. At the time of selection a mark shall be made on each timber to designate the butt end.

Shipment Number.

9. All material collected at a given source and shipped at one time shall be given a shipment number or other designation, which shall be incorporated in the test records.

(*C*) *Field Descriptions*

Field Descriptions.

10. Field notes fully describing the material shall be carefully made by the collector. These notes shall, so far as possible, supply data as outlined in Table I and shall be forwarded for incorporation in the record.

(*D*) *Preparation for and Records of Shipment*

Preparation for Shipment.

11. (*a*) The ends of all green timbers shall be given a coating of paint or other suitable substance to retard end drying and end checking, care being taken to retain the butt designation. They shall be close-piled and before and during shipment shall be kept covered with damp shavings or other substance to prevent drying. If conditions are particularly favorable to the development of molds, stains, or decay, the specimens shall first be brushed or sprayed with a dilute solution of copper sulfate, or similar toxic solution.

(*b*) Record shall be made of the shipment routing, bill of lading, kind of shipment, date of shipment, and condition of material when shipped.

TABLE I.—SHIPMENT DESCRIPTION FIELD NOTES.

Project No., *XC* Shipment No., *012*
Tree No., *1* Species, *Longleaf pine*
Locality cut: State, *Florida* County, *Nassau*
Township, *T3N: R25E* Date cut, *April, 1914*
Slope, *Level.* Absolute elevation, *38 ft.* Aspect, ...
Undergrowth, *Small amount—scattered* Soil, *Sandy*
Height, *110 ft.* Seedling or sprout, *Seedling* Age, *241 years*
Crown, *Large, well developed* D.B.H., *26 in.*
Stem, *Clear, straight* Date sawed, *May 12, 1914*
How and when transported from woods, *By wagon, May, 1914*

LIST OF SPECIMENS.

Piece No.	Size of Specimens			Volume, cu. ft.	Feetage, b. m.	Weight, lb. (Show date)
	Length, ft.	Width, in.	Depth, in.			
1	16.10	7.50	15.50	13.00	171	660

REMARKS: Note any other special points which would be of value.

Grouping.

(*c*) Record shall also be made of date of receipt of shipment at destination, its condition and the method of storage. The time elapsing between the sawing of green timbers and their testing should be reduced to a minimum.

II. DISPOSITION AT DESTINATION; MARKING AND STORAGE

12. When the material arrives at the testing laboratory, it shall be divided into two matched groups of timbers of approximately like quality as specified in Section 7, one portion to be tested green and the other to be weighed and placed under cover for air seasoning prior to testing. After the 32-ft. timbers have been cut into 16-ft. lengths, the specimens to be air-dried shall be selected alternately from butt and top cuts.

Marking.

13. The butt end of each 16-ft. specimen shall be designated "*A*" and the top end "*B*". Other symbols shall be given to each timber in classifying it as to density, position in tree, defects, or other factors that are under consideration. The minor test specimens and data forms shall carry such of these symbols as may be necessary to identify them fully.

Storage.

14. (*a*) The material to be tested green shall be close-piled on skids which are free from contact with the soil, and shall be kept covered. It shall not be held long enough to permit seasoning or damage from checking, decay, or insect attack.

(*b*) The ends of the specimens to be air-dried shall, if necessary, be given a suitable coat of pitch, paint, or other substance to retard checking. The specimens shall be open-piled in a place allowing free access and circulation of air, but shall be protected from sunshine, rain, snow, and moisture from the ground and shall not be subjected to artificial heat.

(*c*) All of the timbers to be air-dried shall be weighed when stored and at sufficiently frequent intervals thereafter to afford accurate data on the progress of seasoning. No material shall be considered thoroughly air-dry and fully conditioned for testing until practically constant weight has been reached.[1] (Wood absorbs and gives off moisture with changing atmospheric conditions; consequently it never comes to absolutely constant weight.)

(*d*) When properly seasoned, the timbers shall be surfaced on four sides before being tested.[2]

TESTS

III. KIND AND NUMBER

(*A*) *Major Tests*[3]

Major Bending.

15. (*a*) The structural member proper shall be tested as a beam. (See Sections 19 to 30.)

Compression Perpendicular to Grain.

(*b*) A section 60 in. long shall be cut from the "*A*" or butt end of each beam after test, except when end "*A*" fails by shear in the bending test; in which case the section shall be taken from the "*B*" or top end. A specimen 30 in. long for compression-perpendicular-to-grain test shall be cut from that end of the 60-in. piece which is nearer the point of loading.

---

[1] The many factors which influence the rate of seasoning, such as species, moisture content, and diverse climatic differences, preclude the establishment of a definite limit of loss in weight which may be permitted in green material prior to test.

[2] A desirable condition for testing air-dry material in small sizes may be considered as about 12-per-cent moisture content. Large timbers, such as bridge stringers, however, usually dry slowly, but may be considered conditioned when, during the season of most rapid drying, successive weighings indicate the moisture content is as low as may reasonably be expected, with due consideration to the climatic conditions of the locality. Such seasoning may require from about one to four years.

[3] The procedure outlined utilizes to best advantage the entire major specimen and if carefully followed will not usually admit the inclusion of specimens which have been seriously strained in the major bending test. The compression specimens referred to in Sections 15(*b*) and 15(*c*) necessarily include such defects as are normal to the material under test.

Compression Parallel to Grain. (*c*) Two compression-parallel-to-grain specimens, each 6 by 6 by 24 in., shall be taken from the farther end of the 60-in. piece specified in Paragraph (*b*).

(*B*) *Minor Tests*[1]

Material. 16. (*a*) A 50-in. section shall be cut from the end of the beam opposite that required for the 60-in. specimen specified in Section 15 (*b*). Six 2 by 2 by 50-in. sticks shall be taken from this piece. In case defects make it difficult to obtain certain of the other clear specimens hereinafter provided for, they may be secured from the uninjured portion of the minor static bending specimens after the test covered in Paragraph (*b*) below.

Static Bending. (*b*) Six static bending specimens free from defects shall be taken, one from each of the 50-in. sticks specified in Paragraph (*a*).

Compression Parallel to Grain. (*c*) Six compression-parallel-to-grain specimens free from defects shall be taken, one from each of the 50-in. sticks specified in Paragraph (*a*).

Compression Perpendicular to Grain. (*d*) Three compression-perpendicular-to-grain specimens free from defects shall be taken, one from each of three of the 50-in. sticks specified in Paragraph (*a*).

Hardness. (*e*) Three hardness specimens free from defects shall be taken, one from each of three of the 50-in. sticks specified in Paragraph (*a*) other than those from which the specimens specified in Paragraph (*d*) are taken.

Shear Parallel to Grain. (*f*) Twelve shear specimens free from defects shall be cut, two from each of the 50-in. sticks specified in Paragraph (*a*). One specimen from each pair taken from the same stick shall be tested in radial shear (surface of failure radial to growth rings) and the other in tangential shear (surface of failure tangential to growth rings).

IV. GENERAL INSTRUCTIONS

(*A*) *Photographs of Timbers*

Timbers to be Photographed. 17. All air-dried timbers shall be photographed on four sides both before and after test. All green timbers shall be photographed on four sides after test only. The middle of the length of the beam, the load and support points, and the order of occurrence of the failures shall be indicated so as to show in the photograph; if necessary to bring them out in the photograph the failures should be penciled or pointed.

---

[1] The procedure outlined utilizes to best advantage the entire major specimen and if carefully followed will not usually admit the inclusion of specimens which have been seriously strained in the major bending test. As specified in Section 26 of the Tentative Methods of Testing Small Clear Specimens of Timber (Serial Designation: D 143 - 24 T) of the American Society for Testing Materials, p. 939, the minors selected shall be free from defects which will affect the properties under consideration.

(*B*) *Moisture Control*

Control of Moisture Content.

18. (*a*) As specified in Section 14 (*c*), the major specimens to be tested in the air-dry condition shall be brought to practically constant weight before test. All tests shall be carried out in such a manner as to prevent large changes in moisture content.

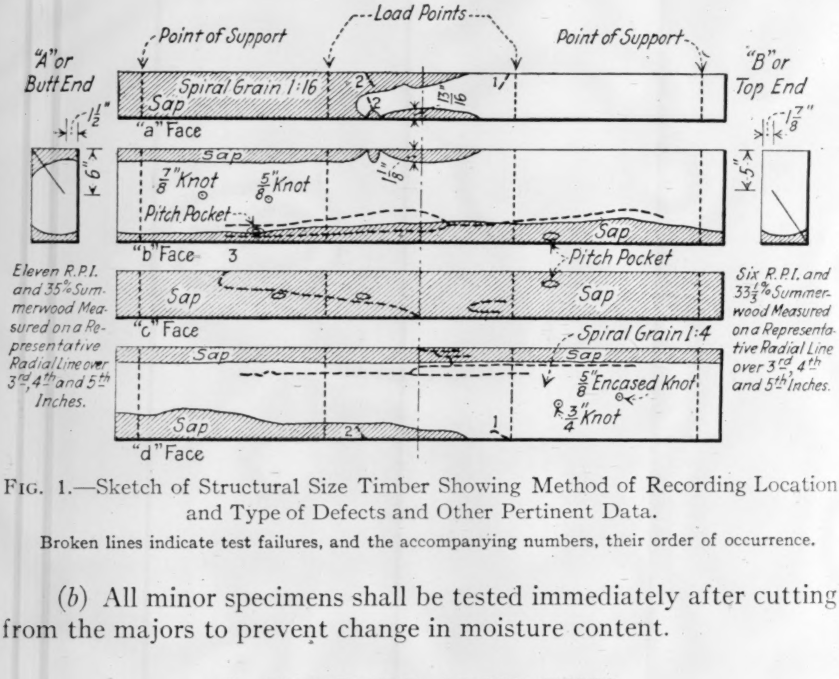
Load Points
Point of Support
Point of Support
"A" or Butt End
"B" or Top End
Spiral Grain 1:16
Sap
2
2
1
13/16"
"a" Face
1 1/2"
1 7/8"
6"
5"
Sap
1/8"
7/8" Knot
5/8" Knot
Pitch Pocket
Sap
"b" Face
3
Pitch Pocket
Eleven R.P.I. and 35% Summerwood Measured on a Representative Radial Line over 3rd, 4th and 5th Inches.
Sap
Sap
Six R.P.I. and 33 1/3% Summerwood Measured on a Representative Radial Line over 3rd, 4th and 5th Inches.
"c" Face
Spiral Grain 1:4
Sap
Sap
5/8" Encased Knot
3/4" Knot
Sap
2
1
"d" Face

FIG. 1.—Sketch of Structural Size Timber Showing Method of Recording Location and Type of Defects and Other Pertinent Data.

Broken lines indicate test failures, and the accompanying numbers, their order of occurrence.

(*b*) All minor specimens shall be tested immediately after cutting from the majors to prevent change in moisture content.

V. PROCEDURE—MAJOR TESTS

(*A*) *Static Bending Test of Structural Size Timber*

Size and Weight.

19. (*a*) The beam shall be weighed before test. The length and the actual depth and width at the center shall be measured.

(*b*) For non-rectangular beams or beams non-uniform in section data shall be secured from which the exact size and shape of the section at any point throughout the length may be obtained.

Additional Marking.

20. In addition to the markings previously made, the four faces shall be lettered "*a*," "*b*," "*c*," and "*d*," beginning with *a* for the

face to which the load is applied and proceeding successively to the right (clockwise) when viewed from the "*A*" or butt end of the timber.

Sketch of Beam.

21. As part of the record, a sketch shall be made of the faces and ends of each beam showing the size, location, and type of defects, including cross-grain,[1] the distribution of sapwood and heartwood, the location of pith, when present, and the direction of the annual rings (see Fig. 1).[2] Detailed record shall also be made of other defects which may be present, such as crook, bow, cup, and twist.[3] The number of rings per inch and proportion of summerwood at both ends shall also be recorded.

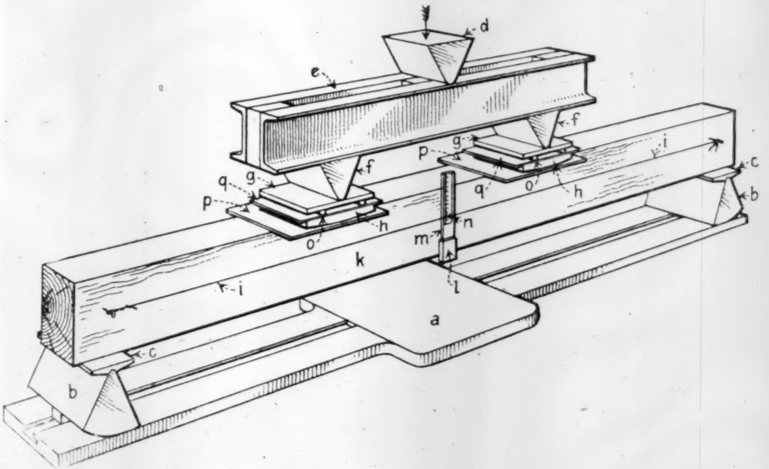

FIG. 2.—Diagrammatic Sketch Showing Method of Conducting Static Bending Test of Structural Sizes of Timber.

Loading, Span and Supports.

22. (*a*) For timbers in structural sizes such as bridge stringers and joists, third-point loading over a span length of 15 ft. shall be used. Knife edges rigidly attached to an auxiliary beam which in turn is hinged by a knife edge shall be used in applying the load. The supporting knife edges shall preferably be of the half-rocker type,

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[1] Cross-grained wood is that in which the wood cells or fibers do not run parallel with the axis of the piece. Cross-grain may be classified as spiral, diagonal, dip, wavy, curly, and interlocking. Definitions of these terms may be found in U. S. Department of Agriculture *Circular No. 296*, p. 60. The presence of diagonal and spiral grain is usually indicated by surface checks; these invariably follow the direction of the grain. The amount of cross-grain in any portion of a timber may be expressed by the slope of the fibers (or checks) on each face with respect to the edges of the piece. Thus, a slope of 1 in 10 indicates a departure of the fibers from the direction of the axis of the specimen of 1 in. in 10 in. of length.

[2] Cross-section paper or quadrille-ruled note book paper is recommended for conveniently making this sketch of the beam to scale.

[3] For definitions of these terms, see U. S. Department of Agriculture *Circular No. 296*, p. 65.

and shall be so placed as to rock outward. To prevent accident or damage from their being thrust suddenly outward on failure of the specimen, they should be tied together by means of a slack chain or cable. Metal bearing plates 6 in. in width and not less than $\frac{1}{2}$ in. in thickness and extending entirely across the face of the beam shall be used over the supporting knife edges. (See Fig. 2.)

(*b*) When beams are tested with respect to particular uses, the dimensions shall be such as to simulate actual conditions as closely as practicable.

(*c*) Fabricated beams such as I or box types shall be full size or solid at the loading points without abrupt change from the solid to the normal beam section.

(*d*) Center loading shall not be used for beams over 4 in. in depth when the span-depth ratio is 14 or less.

Bearing Blocks. 23. (*a*) When testing beams under third-point loading on a span equal to 14 times the beam depth the load shall be applied through bearing blocks extending entirely across the face of the beam and having a radius of curvature three times the depth of the beam for a chord length at least equal to the depth of beam. Additional bearing may be obtained by continuing the curvature in both directions at a radius equal to twice the depth of the beam.

(*b*) For beams loaded at the center, the radius of the bearing block shall be one-half that specified for third-point loading under Paragraph (*a*).

(*c*) Whenever possible, span-depth ratios between 11 and 15 shall be used. For span-depth ratios less than 14, the radius of curvature of the bearing blocks shall be proportionally increased over that specified in Paragraphs (*a*) and (*b*).

(*d*) Bearing blocks of the form and size shown in Fig. 3 shall be used at the load points in testing timbers in structural sizes, such as 6 by 12-in. and 8 by 16-in. bridge stringers, on a 15-ft. span.

(*e*) Where the depth of beam is greater than 4 in., a thin steel plate slightly wider than the beam shall be placed between the loading block and the beam. For beams up to 6 in. in depth, the thickness of this plate shall be from $\frac{3}{32}$ to $\frac{1}{8}$ in. For greater depth the thickness of plates shall be increased slightly to about $\frac{5}{32}$ in. for timbers 6 by 12 in. or 8 by 16 in. in cross-section.

(*f*) For fabricated sections such as airplane I and box beams up to 6 in. in depth, the plate shall be from $\frac{1}{16}$ to $\frac{3}{32}$ in. in thickness.

(*g*) Metal bearing plates and rollers shall be used between each bearing block and its corresponding knife edge. The plates between rollers and knife edges shall be not less than $1\frac{1}{4}$ in. in thickness. If the supporting knife edges are of the full-rocker type rather than the half-rocker type recommended in Section 22 (*a*), rollers shall be placed under one loading knife edge only.

Placement of Specimen in Machine.

24. The beam shall be placed in the testing machine symmetrically with respect to the supports. Parallelism shall be obtained at bearing points. In the case of warped beams, wedges or shims shall be used between the plate and the loading or supporting knife edges or both, as may be necessary to obtain an even bearing before the load is applied.[1] In the case of timbers containing defects, the load shall be applied to the poorer of the loading faces.

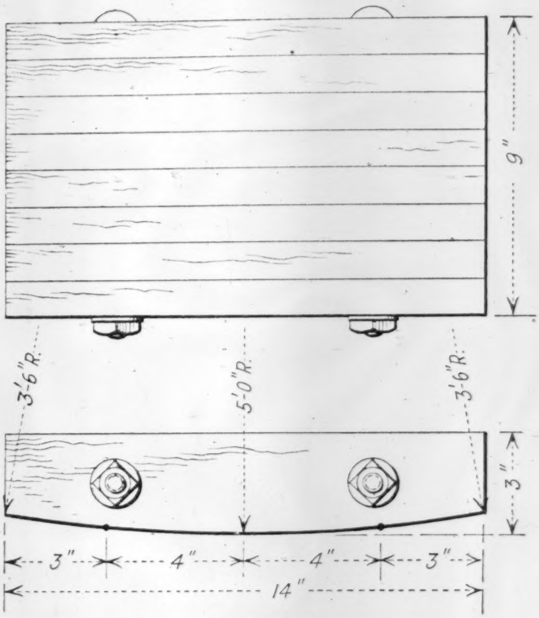

FIG. 3.—Details of Bearing Block for Timbers 12 to 16 in. in Depth When Tested in Third-Point Loading over 15-ft. Span.

Rate of Application of Load.

25. (*a*) The load shall be applied continuously, and with a uniform motion of the movable head throughout the test.

(*b*) *Case 1.*—Beams 4 in. or less in depth when containing defects, or 8 in. or less in depth when free from defects, shall be tested at a rate of fiber strain of 0.0015 in. per inch of outer fiber length per minute.[2]

---

[1] The use of shims or wedges is recommended in preference to planing because in certain cases the latter procedure may effect changes in section where undesirable.

[2] For tolerance on rate of motion of movable head see Sec. 51.

Case 2.—Beams over 4 in. in depth when containing defects, or over 8 in. in depth when free from defects shall be tested at a rate of fiber strain of 0.0007 in. per inch of outer fiber length per minute.[1]

(*c*) For two symmetrical concentrated loads the rate of motion of the movable head of the testing machine may be calculated from the formula:

$$N = \frac{z\,a}{3\,d}\,(3\,L - 4\,a),$$

where N = the rate of motion of moving head in inches per minute;
z = the unit rate of fiber strain in inches per inch of outer fiber length per minute;
a = the distance from support to adjacent load in inches;
d = the depth of beam in inches;
L = the span in inches.

For example, in testing beams 16 in. in depth under third-point loading and on a 15-ft. span, the rate of motion of movable head shall be 0.26 ±0.065 in. per minute.[1]

(*d*) For center loading, the rate of motion of the movable head of the testing machine may be calculated from the formula:

$$N = \frac{zL^2}{6\,d}$$

where the same legend applies as under Paragraph (*c*).

Load-Deflection Curves.

26. (*a*) Load-deflection curves shall be plotted throughout the test.[2] The load and deflection at first failure, at the maximum load, and at points of sudden change shall be shown on the curve, although they may have to be interpolated because of not occurring at one of the regular load or deflection increments.

(*b*) The test shall be continued until the maximum load has been well passed. In the event of horizontal shear, the maximum load may occur after such failure.

Method of Determining Deflection.

27. (*a*) Deflections of the beam at mid-height at the center of the span with respect to points at mid-height immediately above the supports shall be taken to the nearest 0.01 in.

(*b*) Deflection may be read directly by means of a wire stretched between nails driven at mid-height of the beam immediately above the supports and extending across a scale attached at mid-height at the center of the span. Fig. 2 illustrates the method of test. A telescope or reading glass will be found useful in observing the deflections. When a reading glass is used parallax shall be prevented by placing a reflecting surface adjacent to the scale in order that the wire and its image may be made to coincide.

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[1] Tolerance in accordance with Section 51.

[2] See Fig. 1 of the Appendix for a sample static-bending data sheet and Fig. 2 of the Appendix for a sample computation data card.

(*c*) Where special refinement is desired, deflection readings may be taken simultaneously on both sides of the beam, the wires (Paragraph (*b*)) being supported over free running pulleys and held taut with small suspended weights.

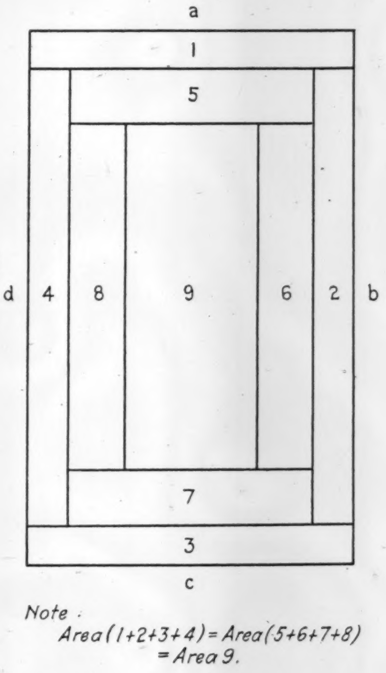


FIG. 4.—Cross-Section of Timber Showing Method of Cutting Up Moisture Distribution Sections.

Description of Failures.

28. The failures shall be described in detail as to type, manner and order of occurrence and position in beam. The descriptions of the failures shall be suitably recorded and correlated with the load-deflection curves. The failures shall be sketched on the drawing of the beam referred to in Section 21, with notations as to the order of their occurrence. The section of the beam containing the failure shall be held for examination and reference until analysis of the data has been completed.

Identification Sample. 29. A section of the beam at least 2 in. in length shall be retained for purposes of identification and future reference. The number of rings per inch and proportion of summerwood shall be recorded for this section.

Specimens for Moisture Determinations. 30. Two sections 1 in. in length shall be cut from near the place of failure for moisture determinations. One of these shall be used for determining the average moisture content of the test specimen. The other, which may be termed a moisture-distribution section, shall be used for determining the moisture content of different portions of the cross-section and shall be sawn into parts according to the pattern shown in Fig. 4. Moisture determinations in each case shall be made in accordance with the procedure specified in Sections 44 to 48.

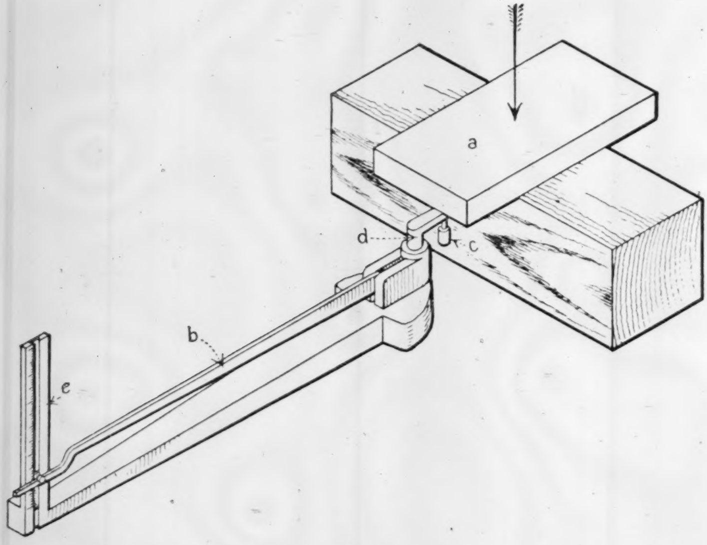


FIG. 5.—Diagrammatic Sketch of Method of Conducting Compression-Perpendicular-to-Grain Test.

(B) *Compression Perpendicular to Grain*

Size of Specimen. 31. The compression-perpendicular-to-grain tests shall be made on specimens 30 in. in length and of the cross-section of the major beam. The actual width and length shall be measured and recorded, and all defects shall be described.

Loading. 32. The load shall be applied through a metal plate 6 in. in width placed across a clear face of the specimen at the center of the length and at right angles to it. The load shall be applied to a face which corresponds to either the loading or supporting face of the static bending specimen. (Section 24.) (See Fig. 5.)

Rate of Application of Load.

33. (*a*) The load shall be applied continuously throughout the test at a rate of motion of movable head[1] determined from the formula:[2]

$$N = 0.0175\, d^{\frac{4}{9}}$$

where N = the rate of motion of moving head in inches per minute; and

d = the depth of beam in inches.

(*b*) For the specimens 8 by 16 in. in cross-section, for example, the rate of descent of the movable head shall be 0.060 ± 0.015 in. per minute.[3]

Load-Compression Curves.

34. Load-compression curves[4] shall be taken for all specimens until the elastic limit has been well passed, after which the test shall be discontinued. Compression readings shall be taken to 0.001 in.

Weight and Moisture Content.

35. The specimen shall be weighed after test and two sections shall be cut near the place of failure for moisture determinations. One of these shall be used for determining the average moisture content of the specimen. The other, which may be termed a moisture distribution section, shall be used for determining the moisture content of different portions of the cross-section and shall be sawn into parts according to the pattern shown in Fig. 4. Moisture determinations in each case shall be made in accordance with the procedure specified in Sections 44 to 48.

(*C*) *Compression Parallel to Grain*

Size of Specimen.

36. The major compression-parallel-to-grain tests shall be made on the 6 by 6 by 24-in. specimens prepared from the pieces specified in Section 15 (*c*). The actual cross-section dimensions, the rate of growth, and the percentage of summerwood shall be determined and recorded for each specimen. All defects shall be described.

End Surfaces.

37. Care shall be exercised in preparing the compression-parallel-to-grain test specimens to make the end surfaces plane, parallel, and normal to the axis of the specimen.[5]

---

[1] For tolerance on rate of motion of movable head see Section 51.

[2] Tests are now in progress to establish more definitely the proper rate of application of load; therefore, the requirement of this section may be changed on the completion of the study.

[3] Tolerance in accordance with Section 51.

[4] See Fig. 4 of the Appendix for a sample compression-perpendicular-to-grain data sheet and Fig. 3 of the Appendix for a sample computation data card.

[5] A sharp fine-toothed saw of either the cross-cut or "novelty" cross-cut type is indispensable for obtaining smooth end surfaces. Power equipment with accurate table guides is especially recommended for this work, though miter-box hand sawing is permissible. Hand planing of the ends, if carefully done, is sometimes advisable.

Spherical Bearing.

38. (*a*) A spherical bearing block shall be used to prevent eccentricity of loading. The radius of the sphere shall be as small as practicable, in order to facilitate adjustment of the bearing plate to the specimen. The suspended type of spherical bearing, to be used on top of the specimen, is especially recommended. The size of the compression plate shall be slightly larger than is necessary to encompass the end of the specimen when the latter is centered on the head.

(*b*) The adjustment of the suspended spherical bearing block may be accomplished by keeping the compression plate in motion about its bearing as contact is made with the specimen.

(*c*) In the spherical bearing block for use on the weighing table, adjustment shall be made by moving the bearing plate with the specimen centered thereon.

Rate of Application of Load.

39. The load shall be applied continuously throughout the test at a rate of motion of the movable head of 0.036 ± 0.009 in. per minute.[1]

Records.

40. The maximum load obtained shall be recorded, together with a description and sketch of the failure. The section of the specimen containing the failure shall be held for examination and reference until analysis of the data has been completed.

Position of Test Failures

41. In order to obtain satisfactory and uniform results, the failures shall be made to develop in the body of the specimen. With specimens of uniform cross-section this may be obtained by having the ends properly prepared and dried to a slightly lower moisture content than the body. With green material, it will usually suffice to close-pile the specimens, cover the body with a damp or wet cloth, and expose the ends for a short time. For air-dry material it may sometimes be advisable, should the failures in test indicate that a slight end drying is necessary, to pile the specimens in a similar manner and place them in a desiccator.

Weight and Moisture Content.

42. The specimen shall be weighed after test, and a moisture section shall be cut from the body of the piece near the failure. Moisture determinations shall be made in accordance with the procedure specified in Sections 44 to 48.

VI. PROCEDURE—MINOR TESTS

43. The procedure for the conducting of minor tests shall conform to the procedure specified in the Tentative Methods of Testing Small Clear Specimens of Timber (Serial Designation: D 143 – 24 T) of the American Society for Testing Materials.[2]

---

[1] Tolerance in accordance with Section 51.

[2] See p. 939.

VII. MOISTURE DETERMINATIONS

Selection of Samples. 44. The samples for moisture determinations shall be selected as hereinbefore described for each test.

Cutting of "Distribution" Sample. 45. The moisture-distribution specimens shall be cut into sections according to Fig. 4, as specified in Sections 30 and 35.

Weighing of Moisture Sample. 46. Immediately upon obtaining any moisture sample, all loose splinters shall be removed and the sample weighed.

Drying. 47. The moisture samples shall be open-piled in a ventilated oven and dried at a temperature which shall ultimately be increased to 98° C. ± 3° C. until constant weight is attained, after which the resulting weight shall be carefully determined and recorded as the oven-dry weight. For specimens not over 1 in. in length (in the direction of grain) about 48 hours' continuous drying under the conditions specified is sufficient to bring the specimens to constant weight. For drying longer specimens, considerably more time will be required, since the rate of drying from the side grain surface of wood is only about one-sixth that from the end surface.

Moisture Content. 48. The loss in weight expressed as a percentage of the oven-dry weight as above determined shall be considered the moisture content of the specimen.

VIII. TOLERANCES

(A) Weights

Weights. 49. The weight of test specimens and of moisture samples shall be determined with an error of not more than 0.2 per cent.

(B) Measurements

Measurements. 50. Measurements of test specimens shall be made to the nearest 0.01 in.

(C) Testing Machine Speeds

Testing Machine Speeds. 51. In no case shall the testing machine speed used vary more than 25 per cent[1] from that specified for a given test. The load shall be applied continuously at the required speed throughout the test.

IX. CALIBRATION

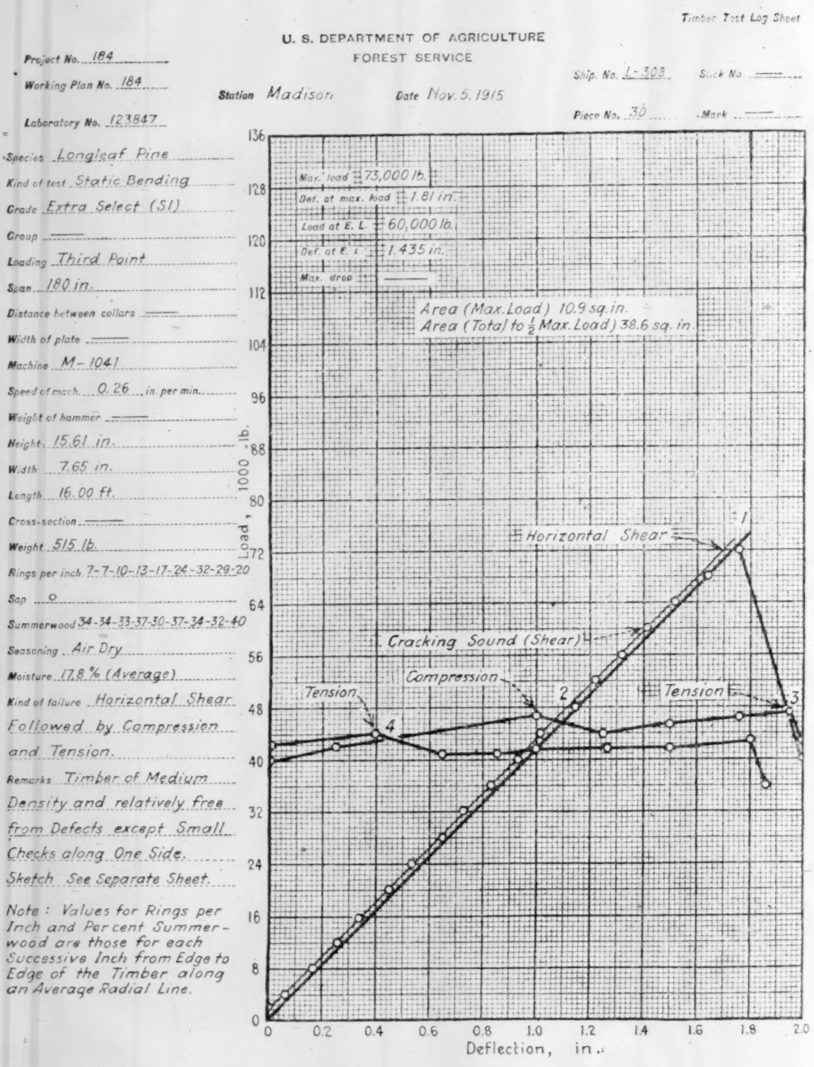
Calibration. 52. All apparatus used in obtaining data shall be calibrated at sufficiently frequent intervals to insure accuracy.[2]

---

[1] Tests by the U. S. Forest Service show that this speed limitation is necessary in order that the stress shall not vary more than 1 per cent due to variation in rate of fiber strain.

[2] See the Standard Methods of Verification of Testing Machines (Serial Designation: E 4) of the American Society for Testing Materials, 1924 Book of A.S.T.M. Standards.

APPENDIX



Timber Test Log Sheet

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Project No. 184
Working Plan No. 184
Laboratory No. 123847

Station Madison
Date Nov. 5. 1915

Ship. No. L-308
Stick No. ——
Piece No. 30
Mark ——

Species Longleaf Pine
Kind of test Static Bending
Grade Extra Select (SI)
Group ——
Loading Third Point
Span 180 in.
Distance between collars ——
Width of plate ——
Machine M-1041
Speed of mach. 0.26 in. per min.
Weight of hammer ——
Height 15.61 in.
Width 7.65 in.
Length 16.00 ft.
Cross-section ——
Weight 515 lb.
Rings per inch 7-7-10-13-17-24-32-29-20
Sap 0
Summerwood 34-34-33-37-30-37-34-32-40
Seasoning Air Dry
Moisture 17.8 % (Average)
Kind of failure Horizontal Shear Followed by Compression and Tension.
Remarks Timber of Medium Density and relatively free from Defects except Small Checks along One Side.
Sketch See Separate Sheet.

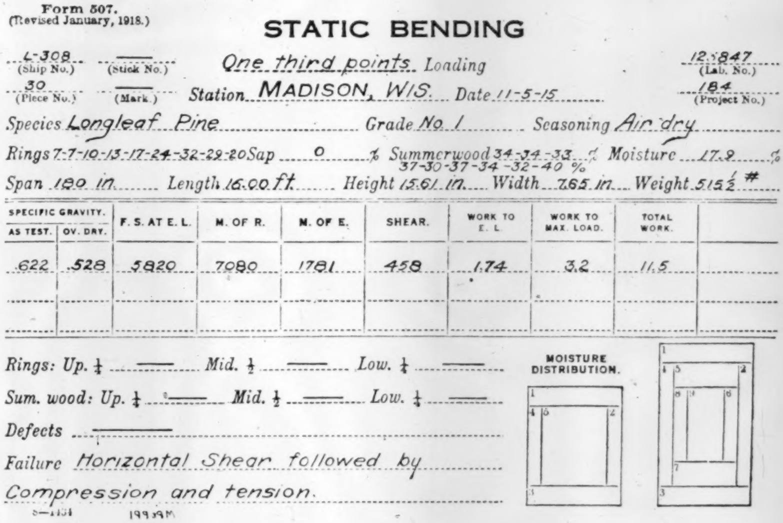
Note: Values for Rings per Inch and Per cent Summerwood are those for each Successive Inch from Edge to Edge of the Timber along an Average Radial Line.

Max. load 73,000 lb.
Def. at max. load 1.81 in.
Load at E. L. 60,000 lb.
Def. at E. L. 1.435 in.
Max. drop ——

Area (Max. Load) 10.9 sq. in.
Area (Total to ½ Max. Load) 38.6 sq. in.

Load, 1000 lb.
136
128
120
112
104
96
88
80
72
64
56
48
40
32
24
16
8
0
Deflection, in.
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Horizontal Shear
1
Cracking Sound (Shear)
Compression
2
Tension
4
Tension
3

FIG. 1.—Sample Data Sheet for Static Bending Test.



Form 507.
(Revised January, 1918.)

STATIC BENDING

L-308 (Ship No.) —— (Stick No.) One third points Loading 125847 (Lab. No.)

30 (Piece No.) —— (Mark.) Station MADISON, WIS. Date 11-5-15 184 (Project No.)

Species Longleaf Pine Grade No. 1 Seasoning Air dry

Rings 7-7-10-13-17-24-32-29-20 Sap 0 % Summerwood 34-34-33-37-30-37-34-32-40 % Moisture 17.9 %

Span 180 in. Length 16.00 ft. Height 15.61 in. Width 7.65 in. Weight 515½ #

SPECIFIC GRAVITY.		F. S. AT E. L.	M. OF R.	M. OF E.	SHEAR.	WORK TO E. L.	WORK TO MAX. LOAD.	TOTAL WORK.	
AS TEST.	OV. DRY.								
.622	.528	5820	7080	1781	458	1.74	3.2	11.5	

Rings: Up. ¼ —— Mid. ½ —— Low. ¼ ——

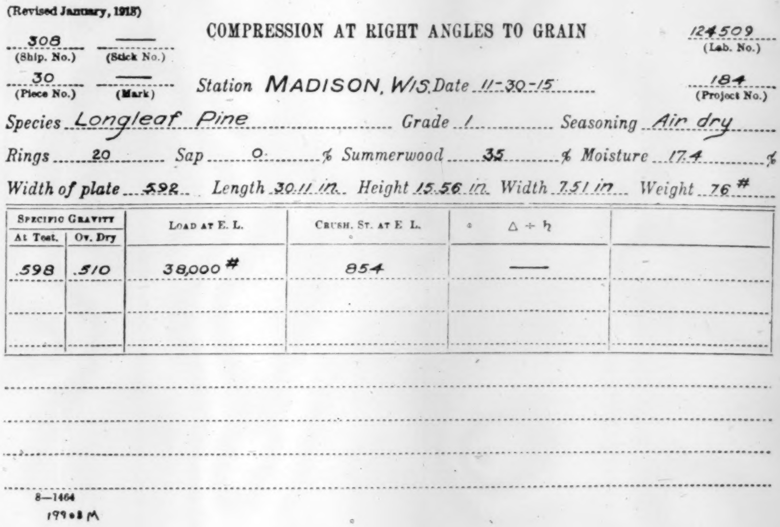
Sum. wood: Up. ¼ —— Mid. ½ —— Low. ¼ ——

Defects ——

Failure Horizontal Shear followed by Compression and tension.

8—1134 19939M

FIG. 2.—Sample Computation Data Card for Static Bending Test.



(Revised January, 1918)

COMPRESSION AT RIGHT ANGLES TO GRAIN

308 (Ship. No.) —— (Stick No.) 124509 (Lab. No.)

30 (Piece No.) —— (Mark) Station MADISON, WIS. Date 11-30-15 184 (Project No.)

Species Longleaf Pine Grade 1 Seasoning Air dry

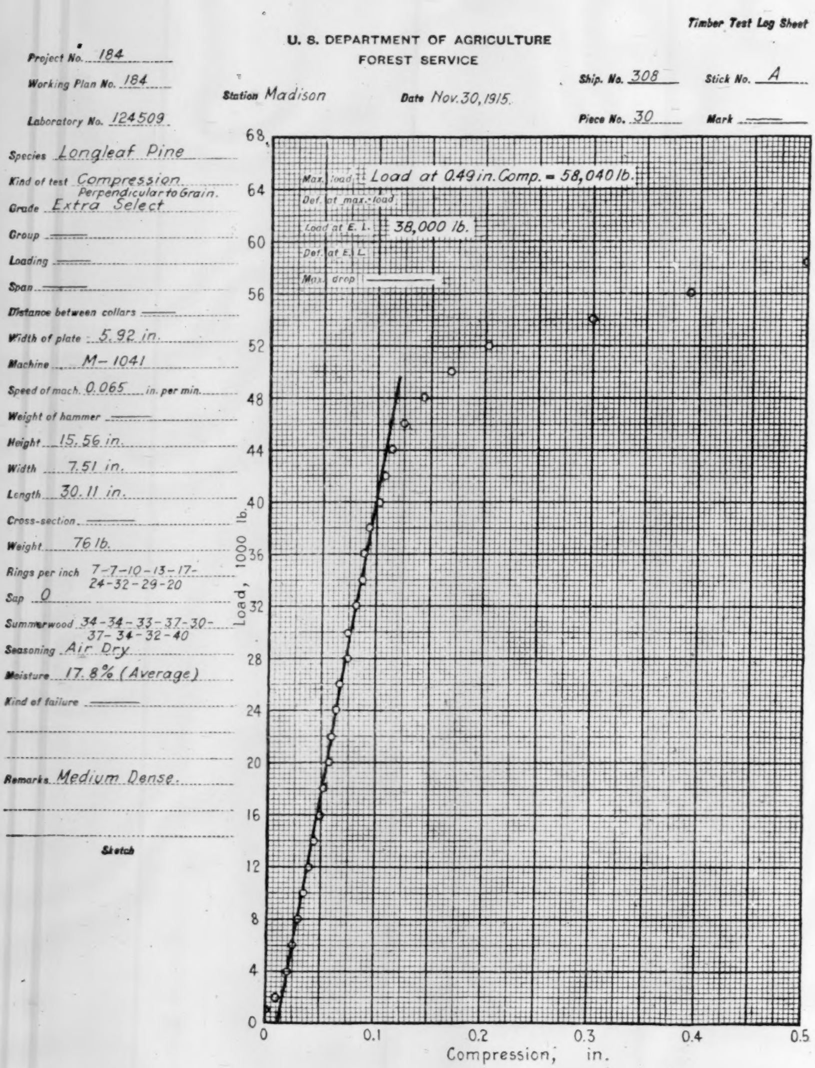
Rings 20 Sap 0 % Summerwood 35 % Moisture 17.4 %

Width of plate 592 Length 30.11 in. Height 15.56 in. Width 7.51 in. Weight 76 #

SPECIFIC GRAVITY		LOAD AT E. L.	CRUSH. ST. AT E. L.	Δ ÷ h	
At Test.	Ov. Dry				
.598	.510	38,000 #	854	——	

8—1464
19908M

FIG. 3.—Sample Computation Data Card for Compression-Perpendicular-to-Grain Test.



Timber Test Log Sheet

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Project No. 184
Working Plan No. 184
Station Madison
Date Nov. 30, 1915.
Ship. No. 308
Stick No. A
Laboratory No. 124509
Piece No. 30
Mark ——

Species Longleaf Pine
Kind of test Compression Perpendicular to Grain.
Grade Extra Select
Group ——
Loading ——
Span ——
Distance between collars ——
Width of plate 5.92 in.
Machine M-1041
Speed of mach. 0.065 in. per min.
Weight of hammer ——
Height 15.56 in.
Width 7.51 in.
Length 30.11 in.
Cross-section ——
Weight 76 lb.
Rings per inch 7-7-10-13-17-24-32-29-20
Sap 0
Summerwood 34-34-33-37-30-37-34-32-40
Seasoning Air Dry
Moisture 17.8% (Average)
Kind of failure ——
Remarks Medium Dense.
Sketch

Max. load Load at 0.49 in. Comp. = 58,040 lb.
Def. at max. load
Load at E. L. 38,000 lb.
Def. at E. L.
Max. drop ——

FIG. 4.—Sample Data Sheet for Compression-Perpendicular-to-Grain Test.

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF ZINC CHLORIDE[1]

Serial Designation: D 199 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1924.

These methods cover the determination of the percentages of insoluble basic zinc chloride, zinc chloride, and iron present in commercial concentrated solutions of zinc chloride or in fused or granulated zinc chloride, for use in the preservative treatment of wood.

Preparation and Standardization of Solutions

Standard Ferrocyanide Solution.—Weigh out 43.25 g. of c.p. potassium ferrocyanide and 14 g. of c.p. crystallized sodium sulfite, dissolve in water and make up to 1 liter at room temperature. Shake thoroughly. Standardize against a zinc solution of known concentration prepared from spelter of known zinc content or from c.p. zinc oxide which has been previously ignited. One cubic centimeter of this solution will be equal to approximately 0.01 g. of zinc. The standardization should be carried out as nearly as possible in the same manner as in the estimation of zinc and approximately the same amount of zinc should be present. Keep the solution in a dark bottle. Shake thoroughly before each using and standardize each time it is used.

Uranium Acetate Indicator.—Dissolve 4.4 g. of c.p. uranium acetate, free from sodium, in 100 cc. of hot water and 2 cc. of glacial acetic acid. Use this as an external indicator on a paraffined plate making the drops as nearly 0.05 cc. as possible.

Hydrogen Peroxide.—The usual laboratory reagent is satisfactory, if fresh.

Hydrogen Sulfide Solution.—The usual laboratory reagent is satisfactory.

---

[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, Forest Products Laboratory, Madison, Wis.

DETERMINATION OF INSOLUBLE OR BASIC ZINC CHLORIDE

Weigh from 10 to 14 g. of the sample, if fused or granulated, from a stoppered weighing bottle, or place an equivalent quantity, if a solution, into a 600-cc. beaker. Add cold water to 400 cc. Stir the contents of the beaker until solution is complete. Allow to settle over night. Filter the solution through a 12.5-cm. filter paper which has previously been washed, dried, and weighed. Receive filtrate in a 1000-cc. graduated measuring flask. Policeman the beaker, and wash the insoluble matter in the filter paper until the filtrate measures 1 liter. Dry the filter paper containing the insoluble matter over night in an oven heated to 100° C. (212° F.). Cool and weigh between clipped watch glasses. Calculate the increase in weight of filter paper to a percentage of the original sample.[1]

Duplicate determinations should check within 1.3 per cent.

DETERMINATION OF ZINC

(*a*) *Volumetric method.* (For use when manganese chloride does not exceed 0.3 per cent.)

The filtrate obtained from the estimation of insoluble basic zinc chloride and whose volume is exactly 1 liter is shaken and three aliquot portions of 100 cc. each are taken with an accurate 100-cc. pipette and transferred into 450-cc. Griffins beakers. Add to each portion 15 g. of ammonium chloride and 5 cc. of concentrated hydrochloric acid. Dilute to 350 cc. and heat nearly to boiling. Titrate slowly with vigorous stirring using a solution of potassium ferrocyanide as the standard reagent and uranium acetate as an external indicator. The average of the three aliquot portions should be reported.

(*b*) *Volumetric Method.* (For use when the manganese chloride equals or exceeds 0.3 per cent.)

To the aliquot portions taken as described under (*a*), 1 cc. of hydrogen peroxide (2 to 3 per cent) and 10 cc. of ammonia (1:1) shall be added. Stand on steam bath until settled. Filter off the manganese, wash beaker and paper twice with hot water. Dissolve the precipitate in the smallest amount of hydrochloric acid (1:1) in the original beaker, heat until all is dissolved; the volume of the solution should be about 20 cc. Reprecipitate the manganese with 1 cc. of hydrogen peroxide and 10 cc. of ammonia, boil, filter, and wash several times with hot water. Add the filtrate to that obtained in the first separation. Add 15 cc. of concentrated hydrochloric acid to the combined filtrate and just neutralize with concentrated ammonia, then add 5 cc. of hydrochloric acid in excess. Dilute to 325 cc. and add 25 cc. of saturated hydrogen sulfide water to remove any traces of hydrogen peroxide, heat and titrate as in (*a*).

---

[1] A Gooch crucible may be used in place of the weighed filter paper.

(*c*) *Gravimetric Method.* (Alternate method, for use when only a limited amount of work is necessary.)

The filtrate obtained from the estimation of insoluble basic zinc chloride and whose volume is exactly 1 liter is shaken and three aliquot portions of 200 cc. each are taken with an accurate pipette and transferred to 450-cc. Griffins beakers. Add to each 4 cc. of concentrated c.p. sulfuric acid. Evaporate on a steam bath; then on a steam plate or hot plate to copious SO_3 fumes, to completely eliminate chlorides. Cool and take up in 100 cc. of hot distilled water. Add 0.5 g. of aluminum powder. Cover with a watch glass. Heat to boiling and boil 5 minutes. Filter through an 11-cm. filter paper. Receive the filtrate in a covered 1000-cc. Griffins beaker. Wash the beaker and filter thoroughly with hot water until a drop of methyl orange indicator placed behind the double fold of filter paper shows no acidity. Exactly neutralize the filtrate with dilute ammonia. Use great care and precision, and carry the neutralization just to the end point.

Add 10 cc. of 0.1 *N* sulfuric acid (3 cc. of concentrated c.p. sulfuric acid in 1000 cc. of water). Dilute to 650 cc. Cover the beaker, and bubble a rapid stream of hydrogen sulfide for one-half to one hour at room temperature.

Settle and filter through a double filter of one 15-cm. and one 11-cm. paper[1] folded together. Transfer the precipitate to the filter paper. Thoroughly policeman the beaker until the zinc sulfide is all removed except a very thin film which clings tenaciously to the glass at the surface of the liquid. Thoroughly wash the beaker and precipitate at room temperature with water saturated with hydrogen sulfide. Repeat washing of filter paper, and precipitate five or six times. Transfer paper and precipitate to an ignited, cooled, desiccated and weighed porcelain crucible of suitable capacity (about 25 to 30 cc.). Carefully dry the paper and precipitate and when dry completely burn off the paper at as low a temperature as possible. When carbon has been completely burned out, ignite the resultant oxide of zinc strongly to as high a temperature as is available, but not higher than can be attained with a laboratory blast lamp with the aid of gas and air. Heat for 30 minutes. After strong ignition, cool the crucible, desiccate and weigh. The increase in weight is zinc oxide. The weight of the zinc oxide multiplied by the factor 1.6749, multiplied by 100, divided by the weight of sample in the aliquot portion taken, equals the percentages of zinc chloride.

---

[1] Ashless paper should be used.

The average of the results obtained with the three aliquot portions analyzed shall be reported. Results should agree within 1.5 per cent.

ESTIMATION OF IRON AND ALUMINA

Weigh 10 g. of the sample, if fused or granulated, or place an equivalent quantity, if a solution, into a suitable beaker and dissolve in 100 cc. of water or dilute to 100 cc., if a solution. Add sufficient hydrochloric acid to dissolve any basic zinc chloride. Add a slight excess of bromine water and boil off excess. Neutralize with a weak solution of sodium carbonate until a permanent precipitate of zinc carbonate is obtained. Add three drops of glacial acetic acid and 2 g. of sodium acetate, and boil. Filter and wash. Redissolve the precipitate in the original beaker with hot hydrochloric acid (1: 1). Reprecipitate the iron and alumina with a slight excess of ammonia, filter and wash free from chlorine. Ignite in a platinum crucible and weigh as $Fe_2O_3+Al_2O_3$.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT FOR USE IN DAMP-PROOFING AND WATERPROOFING BELOW GROUND LEVEL[1]

Serial Designation: D 40 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision

ISSUED, 1917; REVISED, 1922, 1923, 1924.

Scope. 1. These specifications cover asphalt suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing below ground level, under uniformly moderate temperature conditions both during the process of installation and during service.[2]

2. The grade of asphalt covered in these specifications is suitable for damp-proofing and waterproofing foundations, tunnels, subways, etc.

I. SAMPLING.

Sampling. 3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 – 23 T) of the American Society for Testing Materials.[3]

II. PROPERTIES.

Properties. 4. The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

(*a*) Softening point by the Ring-and-Ball method	115 to 145° F. (46.1 to 62.7° C.)
(*b*) Penetration at 25° C. (77° F.), 100 g., 5 sec.	50 to 100
(*c*) Flash point (open cup)	not less than 347° F. (175° C.)
(*d*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr.	not more than 2 per cent

---

[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] Such asphalt is not intended to be heated above 400° F. (204.4° C.) during its application.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 759 (1923).

(*e*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt before heating........................not less than 60 per cent

(*f*) Ductility at 25° C. (77° F.)..............not less than 30 cm.

(*g*) Insoluble in carbon disulfide........not more than 5 per cent

III. METHODS OF TESTING.

Methods of Testing.

5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Softening Point:* Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (Serial Designation: D 36).[1]

(*b*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5).[1]

(*c*) *Flash Point:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92).[1]

(*d*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6).[1]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 22 T).[2]

(*f*) *Insoluble in Carbon Disulfide:* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 – 23 T).[3]

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[1] 1924 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS
FOR
ASPHALT FOR USE IN DAMP-PROOFING AND WATER-PROOFING ABOVE GROUND LEVEL[1]

Serial Designation: D 144 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1923, 1924.

Scope. 1. These specifications cover asphalt suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing above ground level, where not exposed to a temperature exceeding 46° C. (115° F.).[2] It may be used below ground level.

2. The grade of asphalt covered in these specifications is suitable for damp-proofing and waterproofing railroad bridges, tanks, retaining walls, culverts, dams, conduits, etc.

I. SAMPLING.

Sampling. 3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 - 23 T) of the American Society for Testing Materials.[3]

II. PROPERTIES.

Properties. 4. The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

(*a*) Softening point by the Ring-and-Ball method	150 to 170° F. (65.5 to 76.7° C.)
(*b*) Penetration at 46.1° C. (115° F.), 50 g., 5 sec.	not more than 100
Penetration at 25° C. (77° F.), 100 g., 5 sec.	25 to 50

---

[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] Such asphalt is not intended to be heated above 450° F. (232.2° C.) during its application.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 759 (1923).

Penetration at 0° C. (32° F.), 200 g., 60 sec. . . . . not less than 10

(c) Flash point (open cup) . . . . not less than 400° F. (204.4° C.)

(d) Loss on heating at 163° C. (325° F.), 50 g., 5 hr. . . . . not more than 1 per cent

(e) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt before heating. . . . . not less than 60 per cent

(f) Ductility at 25° C. (77° F.) . . . . not less than 15 cm.

(g) Insoluble in carbon disulfide . . . . not more than 1 per cent

III. METHODS OF TESTING.

Methods of Testing.

5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(a) *Softening Point:* Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (Serial Designation: D 36).[1]

(b) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5).[1]

(c) *Flash Point:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92).[1]

(d) *Loss on Heating:* Standard Method of Test for loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6).[1]

(e) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 22 T).[2]

(f) *Insoluble in Carbon Disulfide:* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 – 23 T).[3]

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[1] 1924 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS
FOR
HIGH-CARBON COAL-TAR PITCH FOR USE IN DAMP-PROOFING AND WATERPROOFING BELOW GROUND LEVEL[1]

Serial Designation: D 42 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1917; REVISED, 1922, 1923, 1924.

Scope. 1. These specifications cover high-carbon coal-tar pitch suitable for use as a mopping-coat in damp-proofing or as a plying-cement in the construction of a membrane system of waterproofing below ground level, under uniformly moderate temperature conditions both during the process of installation and during service.[2]

2. The grade of high-carbon coal-tar pitch covered by these specifications is suitable for damp-proofing and waterproofing foundations, tunnels, subways, etc.

I. SAMPLING.

Sampling. 3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 - 23 T) of the American Society for Testing Materials.[3]

II. PROPERTIES.

Properties. 4. The coal-tar pitch shall be homogeneous and shall conform to the following requirements:

(*a*) Water..0.0 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)....1.24 to 1.34

(*c*) Softening Point[4] (Cube-in-Water Method).. 110 to 140°F. (43.3 to 60.0° C.)

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] Such coal-tar pitch is not intended to be heated above 300° F. (148.8° C.) during its application.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 759 (1923).

[4] The Softening Point (Cube-in-Water Method) specified should have a range of not over 10° F. within the limits given in Section 4 (*c*).

(*d*) Distillation Test:

Total distillate, by weight, 0.0 to 300° C. (32 to 572° F.)........................not more than 12.0 per cent
Residue, by weight....................not less than 88.0 "

(*e*) Specific gravity at 38°/25° C. (100°/77° F.) of total distillate to 300° C. (572° F.) ....not less than 1.03
(*f*) Ductility at 25° C. (77° F.)........... not less than 50 cm.
(*g*) Insoluble in carbon disulfide...............20 to 35 per cent

III. METHODS OF TESTING.

Methods of Testing. 5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95).[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T).[2]

(*c*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61).[1]

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20).[1]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 22 T).[3]

(*f*) *Insoluble in Carbon Disulfide:* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 - 23 T).[4]

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[1] 1924 Book of A. S. T. M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 764 (1920).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS

FOR

HIGH-CARBON COAL-TAR PITCH FOR USE IN DAMP-PROOFING AND WATERPROOFING ABOVE GROUND LEVEL[1]

Serial Designation: D 145 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1923, 1924.

Scope.

1. These specifications cover high-carbon coal-tar pitch suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing above ground level, when not exposed to a temperature exceeding 46° C. (115° F.).[2]

2. The grade of high-carbon coal-tar pitch covered in these specifications is suitable for damp-proofing and waterproofing railroad bridges, tanks, retaining walls, culverts, dams, conduits, etc.

I. SAMPLING.

Sampling.

3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 – 23 T) of the American Society for Testing Materials.[3]

II. PROPERTIES.

Properties.

4. The coal-tar pitch shall be homogeneous and shall meet the following requirements:

(*a*) Water..0.0 per cent

(*b*) Specific gravity at 25°/25° C. (77° /77° F.).....1.25 to 1.35

(*c*) Softening Point[4] (Cube-in-Water Method).......................................130 to 155° F. (54.4 to 68.3° C.)

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] Such coal-tar pitch is not intended to be heated above 350° F. (176.6° C.) during its application.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 759 (1923).

[4] The Softening Point (Cube-in-Water Method) should have a range of not over 10° F. within the limits given in Section 4 (*c*).

(*d*) Distillation Test:

Total distillate, by weight, 0 to 300° C. (32 to 572° F.)......................not more than 10.0 per cent
Residue, by weight....................not less than 90.0 "

(*e*) Specific gravity at 38°/25° C. (100°/77° F.) of total distillate to 300° C. (572° F.)..not less than 1.03
(*f*) Ductility at 25° C. (77° F.) .... not less than 20 cmt
(*g*) Insoluble in carbon disulfide..............22 to 37 per cent

III. METHODS OF TESTING.

Methods of Testing.

5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95).[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T).[2]

(*c*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61).[1]

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20).[1]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 22 T).[3]

(*f*) *Insoluble in Carbon Disulfide:* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 - 23 T).[4]

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[1] 1924 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 764 (1920).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS

FOR

HIGH-BITUMEN COAL-TAR PITCH FOR USE IN DAMP-PROOFING AND WATERPROOFING BELOW GROUND LEVEL[1]

Serial Designation: D 200 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Scope. 1. These specifications cover high-bitumen coal-tar pitch suitable for use as a mopping-coat in damp-proofing or as a plying-cement in the construction of a membrane system of waterproofing below ground level, under uniformly moderate temperature conditions both during the process of installation and during service.

2. The grade of high-bitumen coal-tar pitch covered by these specifications is suitable for damp-proofing and waterproofing foundations, tunnels, subways, etc.

I. SAMPLING

Sampling. 3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 - 23 T) of the American Society for Testing Materials.[2]

II. PROPERTIES

Properties. 4. The coal-tar pitch shall be homogeneous and shall meet the following requirements:

(*a*) Water....................................0.0 per cent
(*b*) Specific gravity at 25°/25° C. (77°/77° F.)..1.21 to 1.30
(*c*) Softening Point (Cube-in-Water
  Method).............110 to 140° F. (43.3 to 60° C.)

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] *Proceedings*, Am. Soc. Testing Mats. Vol. 23, Part I, p. 759 (1923).

(*d*) Distillation Test:

Total distillate, by weight, 0.0 to 300° C.
(32 to 572° F.)..................not more than 15.0 per cent
Residue, by weight................not less than 85.0 per cent

(*e*) Specific gravity at 38°/25° C. (100°/77° F.) of total distillate to 300° C. (572° F.)......not less than 1.03

(*f*) Ductility at 25° C. (77° F.)........not less than 50 cm.

(*g*) Total Bitumen (Soluble in Carbon Disulfide)........................75 to 90 per cent

III. METHODS OF TESTING

Methods of Testing. 5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95).[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 – 20 T).[2]

(*c*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61).[1]

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20).[1]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 22 T).[3]

(*f*) *Total Bitumen* (*Soluble in Carbon Disulfide*)*:* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 – 23 T).[4]

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[1] 1924 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 764 (1920).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS

FOR

HIGH-BITUMEN COAL-TAR PITCH FOR USE IN DAMP-PROOFING AND WATERPROOFING ABOVE GROUND LEVEL[1]

Serial Designation: D 201 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Scope.

1. These specifications cover high-bitumen coal-tar pitch suitable for use as a mopping-coat in damp-proofing, or as a plying-cement in the construction of a membrane system of waterproofing above ground level, when not exposed to a temperature exceeding 46° C. (115° F.).

2. The grade of high-bitumen coal-tar pitch covered in these specifications is suitable for damp-proofing and waterproofing railroad bridges, tanks, retaining walls, culverts, dams, conduits, etc.

I. SAMPLING

Sampling.

3. The sampling shall be performed in accordance with the Tentative Methods of Sampling Bituminous Materials (Serial Designation: D 140 – 23 T) of the American Society for Testing Materials.[2]

II. PROPERTIES

Properties.

4. The coal-tar pitch shall be homogeneous and shall meet the following requirements:

(*a*) Water....................................0.0 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)..1.22 to 1.31

(*c*) Softening Point (Cube-in-Water
Method).............130 to 155° F. (54.4 to 68.3° C.)

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 759 (1923).

(*d*) Distillation Test:

Total distillate, by weight, 0.0 to 300° C.
(32 to 572° F.)..............not more than 12.0 per cent
Residue, by weight...............not less than 88.0 per cent

(*e*) Specific gravity at 38°/25° C. (100°/77° F.) of total distillate to 300° C. (572° F.)......not less than 1.05
(*f*) Ductility at 25° C. (77° F.)........not less than 20 cm.
(*g*) Total Bitumen (Soluble in Carbon Disulfide)........................73 to 88 per cent

III. METHODS OF TESTING

Methods of Testing

5. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95).[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 – 20 T).[2]

(*c*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61).[1]

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20).[1]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 22 T).[3]

(*f*) *Total Bitumen (Soluble in Carbon Disulfide):* Tentative Method of Test for the Determination of Bitumen (Serial Designation: D 4 – 23 T).[4]

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[1] 1924 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 764 (1920).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 807 (1922).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 751 (1923).

TENTATIVE SPECIFICATIONS
FOR
ASPHALT MASTIC FOR USE IN WATERPROOFING[1]

Serial Designation: D 169 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Scope.

1. (*a*) These specifications cover the materials for asphalt mastic suitable for use in waterproofing, consisting of mastic cake, asphalt cement and mineral aggregate.

(*b*) The grade of asphalt mastic covered by these specifications is suitable for waterproofing bridges, floors, reservoirs, subways, etc.

Properties.

2. This asphalt mastic is a mixture of mastic cake, asphalt cement and mineral aggregate, which at a temperature of approximately 205° C. (400° F.) is sufficiently plastic to be poured into place and compressed with a wooden trowel or equivalent tool into a compact mass.

As used for strictly waterproofing purposes the mastic cake, asphalt cement and mineral aggregate are combined under heat and manual stirring in substantially the following proportions by weight:

Mastic Cake	48 per cent
Asphalt Cement	5 per cent
Mineral Aggregate	47 per cent

Mastic Cake.

3. (*a*) The mastic cake shall conform to the following requirements:

Weight per cake	not more than 75 lb.
Soluble in pure benzol	14 to 18 per cent by weight
Insoluble in pure benzol	82 to 86 per cent by weight

(*b*) The matter soluble in pure benzol shall be asphalt cement, which after recovery from the mastic cake shall conform to the requirements of the Tentative Specifications for Asphalt Cement, 25 to 30 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements (Serial Designation: D 163 - 23 T) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 721 (1923).

(*c*) The matter insoluble in pure benzol shall be granular mineral matter which after recovery from the mastic cake shall conform to the following requirements as to grading:

Passing 200-mesh sieve	not less than	25 per cent
Passing 10-mesh sieve, retained on 50-mesh sieve	not more than	25 per cent
Retained on 10-mesh sieve	not more than	1 per cent

Asphalt Cement. 4. The asphalt cement shall conform to the requirements of the Tentative Specifications for Asphalt Cement, 25 to 30 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements (Serial Designation: D 163 – 23 T) of the American Society for Testing Materials.[1]

Mineral Aggregate. 5. The mineral aggregate shall be gravel or crushed stone, and sand conforming to the following requirements as to grading:

Passing 200-mesh sieve	none	
Passing 50-mesh sieve, retained on 200-mesh sieve	not more than	25 per cent
Passing 10-mesh sieve, retained on 50-mesh sieve	not less than	25 per cent
Passing 4-mesh sieve, retained on 10-mesh sieve	not less than	50 per cent
Retained on 4-mesh sieve	not more than	10 per cent

Methods of Testing. 6. The properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (Serial Designation: D 147 – 24 T) of the American Society for Testing Materials.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 721 (1923).

[2] See p. 1017.

TENTATIVE SPECIFICATIONS
FOR
BITUMINOUS GROUT FOR USE IN WATERPROOFING ABOVE GROUND LEVEL[1]

Serial Designation: D 170 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Scope.

1. (*a*) These specifications cover the materials for bituminous grout suitable for use in waterproofing above ground level, either as a protective covering of membrane systems of waterproofing or for bedding brick or filling the joints or flooding the surface of a brick protective covering.

(*b*) The grade of bituminous grout covered by these specifications is suitable for waterproofing railroad bridges, culverts, subways, etc.

Properties

2. This bituminous grout is a mixture of substantially 45 parts by weight of bituminous binder and 55 parts by weight of mineral aggregate as coarse as sand, which becomes sufficiently fluid when heated to approximately 205° C. (400° F.), to flow without mechanical manipulation, and which on cooling congeals to a compact mass.

Bituminous Binder.

3. The bituminous binder shall consist of either asphalt binder or coal-tar pitch as follows:

(*a*) The asphalt binder shall conform to the requirements of the Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level (Serial Designation: D 144 – 24 T) of the American Society for Testing Materials.[2]

(*b*) The coal-tar pitch shall conform to either of the following tentative specifications of the American Society for Testing Materials:

(1) Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 42 – 24 T);[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] See p. 1001.

[3] See p. 1003.

(2) Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 200 – 24 T).[1]

Mineral Aggregate. 4. The mineral aggregate shall consist of silicious sand, all of which will pass a 20-mesh sieve, and not more than 5 per cent of which will pass a 200-mesh sieve.

Methods of Testing. 5. The properties enumerated in Sections 2 and 4 shall be determined in accordance with the Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (Serial Designation: D 147 – 24 T) of the American Society for Testing Materials.[2]

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[1] See p. 1007.

[2] See p. 1017.

TENTATIVE SPECIFICATIONS
FOR
BITUMINOUS GROUT FOR USE IN WATERPROOFING BELOW GROUND LEVEL[1]

Serial Designation: D 171 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924.

Scope.

1. (*a*) These specifications cover the materials for bituminous grout suitable for use in waterproofing below ground level, either as a protective covering of membrane systems of waterproofing or for bedding brick or filling the joints or flooding the surface of a brick protective covering.

(*b*) The grade of bituminous grout covered by these specifications is suitable for waterproofing tunnels, subways, etc.

Properties.

2. This bituminous grout is a mixture of substantially 45 parts by weight of bituminous binder and 55 parts by weight of mineral aggregate as coarse as sand, which becomes sufficiently fluid when heated to approximately 149° C. (300° F.), to flow without mechanical manipulation, and which on cooling congeals to a compact mass.

Bituminous Binder.

3. The bituminous binder shall consist of either asphalt binder or coal-tar pitch as follows:

(*a*) The asphalt binder shall conform to the requirements of the Tentative Specifications for Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 40 - 24 T) of the American Society for Testing Materials.[2]

(*b*) The coal-tar pitch shall conform to either of the following tentative specifications of the American Society for Testing Materials:

(1) Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 42 - 24 T).[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

[2] See p. 999.

[3] See p. 1003.

(2) Tentative Specifications for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (Serial Designation: D 200 - 24 T).[1]

Mineral Aggregate. 4. The mineral aggregate shall consist of silicious sand, all of which will pass a 20-mesh sieve, and not more than 5 per cent of which will pass a 200-mesh sieve.

Methods of Testing. 5. The properties enumerated in Sections 2 and 4 shall be determined in accordance with the Tentative Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (Serial Designation: D 147 - 24 T) of the American Society for Testing Materials.[2]

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[1] See p. 1007.

[2] See p. 1017.

TENTATIVE METHODS OF TESTING BITUMINOUS MASTICS, GROUTS AND LIKE MIXTURES[1]

Serial Designation: D 147 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED, 1923, 1924.

I. DEFINITIONS.

Scope.

1. These methods apply to bituminous mastics, grouts and like mixtures, which may be classified and defined as follows:

Bituminous Grout.—A mixture of bituminous material as a binder and sandy mineral matter as an aggregate, which between 149° C. (300° F.) and 205° C. (400° F.) becomes sufficiently fluid to flow into place without mechanical manipulation, and which on cooling congeals to a compact mass.

Asphalt Mastic.—(1) A mixture containing asphaltic material as a binder and graded mineral matter as an aggregate, or (2) pulverized native rock asphalt (to which asphaltic material may have been added); either of which at approximately 205° C. (400° F.) may be poured into place but which requires a trowel to form it into a compact mass.

Asphalt Mastic Cake.—A mixture containing asphaltic material as a binder and an aggregate consisting chiefly of calcareous or siliceous dust cast into the form of blocks or "cakes" and adapted for use in preparing asphalt mastic.

II. PREPARATION OF SAMPLES.

Preparation of Samples.

2. (*a*) Bituminous grouts shall be heated in an oven or on a hot plate in a pan or other suitable container at the lowest possible temperature to prevent overheating and volatilization, and when sufficiently fluid, shall be thoroughly stirred to insure a uniform sample, whereupon 10 to 30 g. shall be taken for analysis.

(*b*) Asphalt mastics or mastic cake shall be warmed on a hot plate or in a hot oven until soft enought to be broken up or stirred so that a representative sample for analysis may be taken. The amount taken for analysis will depend upon the amount of coarse gravel or stone in the mixture. The larger the gravel or stone, the larger will be the sample required for accuracy. The size of samples to be taken shall be as follows: Where all particles pass a 10-mesh sieve, 10 to 30 g.; where 25 per cent of the aggregate is retained on a 10-mesh sieve, 50 g.; where 50 per cent of the aggregate is retanied on a 10-mesh sieve, 100 g.; and where 75 per cent of the aggregate is retained on a 10-mesh sieve, 200 g.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1925, to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 25 W. Forty-third St., New York City.

NOTE.—Where the properties of the extracted bituminous matter are to be determined, 500 g. shall be taken and extracted with pure benzol as described in Sections 4 and 6 and examined as described in Section 7.

III. APPARATUS.

(*A*) *For Analysis of 10 to 30-g. Samples.*

Apparatus, 10 to 30-g. Samples.

3. In cases where a 10 to 30-g. sample is sufficient, the analysis shall be carried out by means of the glass extractor described in Section 8 of the Standard Methods of Testing Rubber Products (Serial Designation: D 15) of the American Society for Testing Materials.[1]

(*B*) *For Analysis of 50 to 500-g. Samples.*

Apparatus, 50 to 500-g. Samples.

4. The apparatus for analysis of samples containing coarser aggregate shall be the large extractor shown in Fig. 1, consisting of a large brass cylinder, through the bottom of which projects a 16-candle-power incandescent carbon filament bulb to supply heat to the extraction apparatus proper, which is held in the upper portion of the cylinder. This apparatus is composed of a cylindrical brass vessel for holding the solvent, a cylindrical wire basket made of 80-mesh wire cloth suspended in the cylinder, and an inverted conical condenser which serves as a top.

IV. PROCEDURE.

(*A*) *Analysis of 10 to 30-g. Samples.*[2]

Procedure.

5. An ordinary Whatman or S. and S. Filter Thimble shall be dried and weighed. The weighed sample shall be placed in the thimble and 40 to 50 cc. of CS_2 poured over the sample. The thimble containing the sample shall be suspended under the condenser by a fine wire bail. The flask shall be cautiously heated by a steam-bath or electric heater just enough to vaporize the solvent. Cold water is circulated through the condenser. The heat evaporates the carbon disulfide in the flask. This condenses upon the condenser and drops back upon

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[1] 1924 Book of A.S.T.M. Standards.

[2] This method and the method for analysis of larger samples are especially adapted for asphalt mastics, grouts and mastic cake. If the binder is coal-tar pitch, the "free carbon" constituent of the binder will remain with the mineral aggregate. The committee has under consideration a possible separate method for analysis of coal-tar mastics.

the sample through which it filters, thus dissolving out the bitumen which collects in the bottom of the flask.

The extraction should be discontinued when the CS_2 drops colorless from the filter. The time of extraction will depend upon the nature of the bitumen and mineral aggregate in the sample and upon the degree of heat applied, the coldness of the water in the condenser and other factors. In some cases extraction may be complete in one hour, in others four or five hours may be necessary.

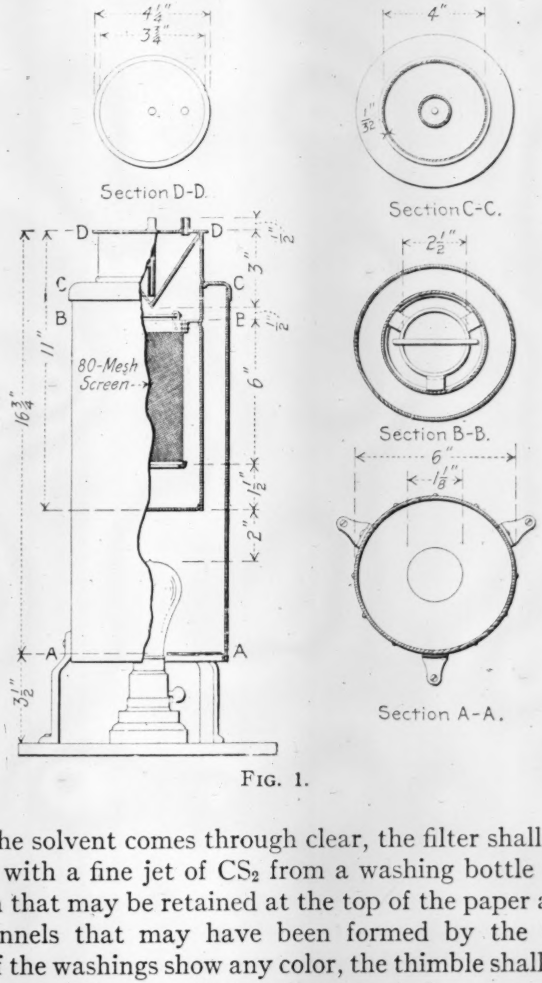

FIG. 1.

When the solvent comes through clear, the filter shall be removed and washed with a fine jet of CS_2 from a washing bottle to wash out any bitumen that may be retained at the top of the paper and to break up any channels that may have been formed by the CS_2 passing through. If the washings show any color, the thimble shall be put back and extraction continued until the solvent again becomes colorless. It shall then be removed, dried carefully, at a low temperature at first to prevent ignition of the absorbed CS_2, and finally to constant weight at 100° C. (212° F.), cooled and weighed.

The solution in the flask shall be rinsed into a weighed porcelain or silica evaporating dish or crucible and the solvent burned off under a hood. The residue shall be ignited over a flame or in a muffle and the ash weighed and the weight added to that of the mineral matter in the filter paper. This is to correct for the fine mineral matter which will be carried through the paper by the solvent. Should there be a considerable amount of ash recovered in this way, and if it is found that the mineral matter is calcium or other carbonate, it shall be recarbonated by repeated treatment with ammonium carbonate solution and finally ignited at a dull red heat. Ordinarily, however, the mineral matter going through the paper will be so small in amount that the difference caused by ignition may be neglected.

The corrected loss in weight on the original sample represents the percentage of bitumen.

The mesh analysis of the mineral aggregate shall be made in accordance with the Standard Method of Mechanical Analysis of Sand or Other Fine Highway Material, except Fine Aggregates Used in Cement Concrete (Serial Designation: D 7) of the American Society for Testing Materials.[1] The extracted residue shall now be transferred from the thimble to the 200-mesh sieve, the paper being gently rubbed to free adhering particles.

The aggregate on the sieve shall be gently rubbed with the fingers to break up lumps and to free any particles of fine dust that might adhere to larger sand particles. The sieve shall be shaken over a piece of paper from side to side with the right hand, striking it sharply against the palm of the left hand until no appreciable amount of dust comes through the sieve on to the paper. The paper shall be cleared from time to time by raising one side with the left hand and rolling off the siftings, so that it can be seen when the sifting is complete.

The material remaining on the 200-mesh sieve shall be weighed and the amount of 200-mesh material which has passed through shall be determined by difference.

This operation shall be repeated upon the coarser sieves in order and the amount passing each sieve and retained on the next finer recorded as percentage of the original sample.

(*B*) *Analysis of 50 to 500-g. Samples.*

6. A large filter paper, 12 or 13 in. in diameter, shall be fitted inside the wire basket of the extractor by folding once more than in

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[1] 1924 Book of A.S.T.M. Standards.

ordinary filtering, or by wrapping it over a form which fits inside the basket (a cylindrical bottle of proper size makes a good form) and placing it inside the basket.

The basket with contained filter paper shall be dried and weighed. The sample shall be weighed and packed in the filter paper in the basket. Care should be taken not to pack all coarse particles in one place and the fine particles in another but to have them mixed together in uniform proportions.

The sample shall be covered with a disk of felt or wad of absorbent cotton to insure even distribution of the dropping solvent, thus preventing it from forming a channel through the sample. The basket shall be suspended in the extractor and 150 to 200 cc. of CS_2 poured over the felt or cotton. The condenser shall be placed over the top and water circulated through it. Current shall be started through the electric lamp underneath the extractor and the extraction carried on exactly as in the smaller glass extractor, but on a larger scale. The time for extraction will vary from 3 to 12 or more hours, depending upon the nature of the sample.

To determine when extraction is complete, the condenser shall be raised and the basket lifted out to observe if drippings are clear. One or two drops caught upon white filter paper should leave but a light stain.

The drying and weighing of the basket, burning off of the solution for correction, and the sifting of the mineral aggregate shall be carried on exactly as in the case of the smaller sample as described in Section 5, except that in sifting mineral aggregates containing coarse stone, it is well to remove the stone by putting the mineral aggregate first through a 10-mesh sieve, as the large stone would injure the 200-mesh sieve.

The stone removed by the 10-mesh sieve may be screened through $\frac{1}{4}$-in., $\frac{1}{2}$-in., and coarser screens in order, as described in the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, except Aggregates used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials[1] and the fine material passing the 10-mesh sieve through 200-mesh and coarser sieves in order, all amounts passing any one screen or sieve and retained on the next finer one being reported as percentage of the original sample.

Thus the ingredients of the mixture may be roughly separated by the use of the proper sized sieves, and examined for physical and chemical characteristics.

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[1] 1924 Book of A.S.T.M. Standards.

NOTE.—The siftings passing the 200-mesh sieve will consist largely of the dust or pulverized rock used in the mixture. The material between the 100-mesh and 10 mesh will consist largely of the sand used in the mixture, with any particles of fine crushed stone within these limits that existed in the original materials. Gravel or broken stone as a rule will be larger than 10 or 8 mesh.

Carbon tetrachloride, benzol, or chloroform may be used instead of carbon disulfide, with the only difference that in the case of noninflammable solvents, the solvent will have to be evaporated from the solution of bitumen to determine the ash for correction instead of burning off directly. When the solvent is expelled, the bitumen can be ignited for ash.

(*C*) *Recovery and Examination of Extracted Bitumen.*

7. The benzol solution containing the asphalt shall be evaporated to a thick viscous liquid on a steam or water bath, then transferred to a steam oven at 105° C. (221° F.) until its weight is nearly equal to the percentage of asphalt calculated in accordance with Section 5. It shall then be transferred to a hot plate and heated carefully with stirring at a temperature not exceeding 121° C. (250° F.) until its weight is exactly that determined in accordance with Section 6.

(*D*) *Solubility of Aggregate in Hydrochloric Acid.*

8. Where the mastic is to be used for acid-proof floors, tank linings, etc., pulverized silica and other materials insoluble in acid are used in preparing the mixture. The most important chemical property, therefore, is solubility or insolubility in mineral acids. This determination may be carried out in the following manner:

About 2.5 g. of the dust, or of the coarser material, or stone which has been previously pulverized in a mortar shall be dried to constant weight at 325° F. The loss will represent any moisture that may have been retained in the material as well as any absorbed solvent that may not have been expelled while drying the sample after extraction.

A 1-g. sample of the dried material shall be placed in a 250-cc. beaker, covered with a watch glass and 10 cc. of concentrated c. p. hydrochloric acid added, diluted with 50 cc. of distilled water. Any lumps shall be broken up by means of a glass stirring rod. Any effervescence which may occur shall be noted. If considerable effervescing takes place, the sample may be said to be carbonate. If all the sample, or practically all, dissolves, the determination need not be carried farther. If apparently insoluble, it shall be heated carefully, brought to boiling for 15 minutes and filtered through a tared Gooch filter, washing the insoluble residue with hot water. It shall be ignited and weighed and the loss reported as the percentage soluble in hydrochloric acid.

TENTATIVE METHODS OF TESTING INSULATING VARNISHES[1]

Serial Designation: D 115 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1922, 1923, 1924.

Material Covered.

1. These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.

I. SPECIFIC GRAVITY.

Specific Gravity.

2. The specific gravity shall be measured with a pyknometer, Westphal balance or with a hydrometer so graduated that the specific gravity can be determined to 0.001. The temperature of the varnish shall be not less than 18° C. (64.4° F.) nor more than 22° C. (71.6° F.) and corrected to 20° C. (68° F.) by applying a correction of 0.0007 per 1° C. (0.0004 per 1° F.).

II. VISCOSITY.

Viscosity.

3. (*a*) The viscosity shall be determined with a Stormer or MacMichael viscosimeter and shall be stated in terms of the viscosity of distilled water determined with the same instrument under the same conditions. The short-tube type of efflux viscosimeter usually employed for lubricating oils is not acceptable. The temperature of the varnish shall be 20° C. (68° F.).

(*b*) The report shall include such details as the kind of instrument used, the size of the counterweight if a Stormer instrument is used, or the size of the wire in case the MacMichael instrument is used, etc.

III. FLASH POINT.

Procedure for Flash Point.

4. The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1925, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, Twenty-first St. and Clinton Ave., Irvington, N. J.

(Serial Designation: D 56) of the American Society for Testing Materials.[1]

IV. TIME OF DRYING.

Test Specimen.

5. (*a*) Specimens for this test shall be pieces of thoroughly cleaned, smooth sheet copper or brass about 3 cm. (1.18 in.) wide and 20 cm. (7.88 in.) long and about 0.127 mm. (0.005 in.) thick.

(*b*) The specimen shall be dipped once in the varnish at a room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The consistency of the varnish shall be first so adjusted by trial that, when dry as determined in accordance with Section 7, the thickness of the film of varnish on each side of the metal shall be between 0.022 mm. (0.0009 in.) and 0.026 mm. (0.001 in.). Care shall be taken before dipping the specimens that the varnish has stood in the dipping tank for a sufficient length of time to be free from air bubbles.

Procedure.

6. (*a*) Specimens of air-drying varnish shall be dried in dust-free air at a room temperature of approximately 20° C. (68° F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain at a room temperature of approximately 20° C. (68° F.) until the varnish is set as indicated when the impression left on the surface by pressing lightly thereon with a finger will not become obliterated by further flow of the material. They are then to be dried in dust-free air in an oven at 105 to 110° C. (221 to 230° F.). At the end of the first 30 minutes, and again at the end of each 10-minute period thereafter, one specimen shall be taken from the oven and examined. In the case of slow-drying varnishes, this 10-minute period may be lengthened at the discretion of the operator.

Time of Drying.

7. The varnish shall be considered dry when a specimen will not stick to itself when folded and pressed together between the thumb and finger at a temperature of approximately 20° C. (68° F.).

V. DIELECTRIC STRENGTH TEST.

Dielectric Strength Test Specimen.

8. (*a*) Specimens for the dielectric strength test shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which shall be at the consistency prescribed in Section 5 (*b*).

(*b*) Each specimen shall be dipped twice, as specified in Section 5 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

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[1] 1924 Book of A.S.T.M. Standards.

(*c*) Specimens of air-drying varnish shall be dried in free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period 600 per cent longer than that determined in accordance with Section 7, provided such period does not exceed 24 hours.

(*d*) Specimens of baking varnish shall be drained and then baked after each dip for a period 300 per cent greater than that determined in accordance with Section 7 provided such period does not exceed 24 hours.

(*e*) The final thickness of the film of varnish on each side of the specimen shall be between 0.044 mm. (0.0018 in.) and 0.052 mm. (0.002 in.).

Procedure.

9. (*a*) The dielectric strength of the two films of varnish shall be determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). The potential shall be applied at a low value and gradually raised at a rate of 0.5 kv. per second. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the films of varnish is to be determined as close to the point of puncture as practicable.

NOTE.—When necessary, in order to get ten punctures, additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.[1]

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 500 volts. The apparatus shall comply with the Standards of the American Institute of Electrical Engineers.

Dielectric Strength.

10. The volts at puncture, the net thickness of insulation and the volts per mil of net thickness shall be reported for each of the ten tests together with the average maximum and minimum volts per mil.

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[1] Standards of the American Institute of Electrical Engineers.

VI. WATER ABSORPTION TEST.

Procedure. 11. Specimens similar to those described in Section 8 shall be immersed in water at a room temperature of approximately 20° C. (68° F.) for a period of 24 hours. Upon removal from the water, the surface water shall be wiped off and dielectric strength tests made immediately as described in Section 9.

Dielectric Strength. 12. The volts at puncture, the net thickness of the insulation and the volts per mil of net thickness shall be reported for each of the ten tests, together with the average, maximum and minimum volts per mil.

VII. HEAT ENDURANCE TEST.

Test Specimens. 13. For the heat endurance test, specimens shall be prepared as in Section 8. After removing not less than 1.27 cm. (0.5 in.) from one edge of the specimens, the number of strips required by Section 14 (*a*) shall be cut from the same edge, each 1.9 cm. (0.75 in.) in width.

Procedure. 14. (*a*) After setting as shown by the test indicated in Section 6 (*b*), the strips referred to in Section 13 shall be placed in a uniformly heated oven in which the temperature is maintained at 100° C. (212° F.) within ± 5° C. (9° F.). A strip shall be removed at the end of 1, 2, 4, 8 and 24 hours respectively and every 24 hours thereafter. These, together with the initial strip, shall be tested as follows at a room temperature of approximately 20° C. (68° F.).

(*b*) Each strip shall be bent through 180 deg. over a rod 0.32 cm. ($\frac{1}{8}$ in.) in diameter. The number of hours of baking at which first cracking in the insulation occurs shall be noted and reported.

VIII. ACID AND ALKALI PROOF TEST.

Test Specimens. 15. The specimens to be used for the test for acid and alkali proofness shall be brass rods 1.5 cm. (0.59 in.) in diameter, 15 cm. (5.90 in.) long and carefully rounded at one end to a radius of 0.75 cm. (0.295 in.). These specimens shall be dipped three times into the varnish, leaving exposed about 3 cm. (1.18 in.) of the rod at the end opposite the rounded end. Each coat shall be dried 25 per cent longer than the period determined in Section 7. Three specimens each shall be prepared for the acid and alkali solutions.

Procedure. 16. (*a*) The three specimens shall be suspended in the acid or alkali whose effect it is desired to determine to within 3 cm. (1.18 in.) of the end of the coated portion of the rod and suitable provision made for detecting the change in the electrical resistance between the rod and the solution. (Note 1.)

(*b*) It is recommended that these tests be made in 10-per-cent solutions as follows:

Sulfuric acid of sp. gr. 1.069 at 60° F. (15.5° C.) or nitric acid of sp. gr. 1.056 at 60° F. (15.5°) C.) or hydrochloric acid of sp. gr. 1.050 at 60° F. (15.5° C.) and sodium hydroxide of sp. gr. 1.115 at 60° F. (15.5° C.).

(*c*) The temperature of the solution shall be kept at approximately 20° C. (68° F.).

NOTE 1. A simple method is to connect a voltmeter between each rod in turn and one side of a 110-volt direct current circuit, the other side of the circuit being connected to the solution through any piece of suitable metal suspended in the solution. The resistance will be inversely proportional to the deflection of the voltmeter pointer, that is, the smaller the deflection, the greater the resistance. Failure of the material will, therefore, be indicated by a sudden increase in the deflection of the voltmeter pointer.

Acid and Alkali Proofness.

17. The resistance between each rod and the solution shall be measured once per day and the number of days elapsing before breakdown occurs shall be taken as the "proofness" of the varnish.

IX. OIL PROOF TEST.

Oil Test Specimen.

18. For the test for the effect of oil, pieces cut from the specimens prepared for the dielectric strength test (Section 8) may be used after they have been punctured and measured.

Procedure.

19. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 100° C. (212° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth

NOTE.—Incipient disintegration of the surface of the varnish may sometimes be detected by examining the oil for turbidity. If a specimen of the oil filtered through filter paper can be distinguished from an unfiltered sample when the two samples are held in front of a strong light, the oil is turbid.

X. DRAINING TEST.

(ALSO KNOWN AS "WORKING VISCOSITY" TEST)

Test Specimen.

20. A strip of bond paper 0.064 mm. (2.5 mils) in thickness, 10.2 cm. (4 in.) in width and 50.8 cm. (20 in.) in length, shall be immersed in the varnish at a room temperature of approximately 20° C. (68° F.) up to a line previously drawn across the paper a few inches from the top. The paper shall be withdrawn at a slow and uniform rate (about 38 cm. (15 in.) per minute), care being taken that the varnish is free from air bubbles. The specimen shall be permitted to drain thoroughly at room temperature while suspended in a

vertical position. It shall then be dried or baked (according to the type of the varnish) until dry as determined in accordance with Section 7.

Measurements. 21. The thickness of the specimen in mils shall be measured at points 5.1 cm. (2 in.), 17.8 cm. (7 in.) and 30.5 cm. (12 in.), respectively, from the line to which the specimen was immersed.

Report. 22. The thickness of each film in mils at the three points specified in Section 21 shall be recorded. The difference between the thickness at the upper point (5.1 cm.) and that at the lower point (30.5 cm.) shall be taken as a measure of the variation in the film thickness caused by draining.

XI. EVAPORATION TEST.

Procedure. 23. One hundred cubic centimeters of the varnish shall be placed in a flat-bottom crystallizing dish approximately 75 mm. (2.95 in.) in diameter and 45 mm. (1.77 in.) in height. It shall be heated to a temperature of 100° F. (37.8° C.) ± 2° F. (1.1° C.) for a period of 7 hours, the sample being exposed to still air in the open room.

Evaporation. 24. The decrease in volume of the sample shall be taken as the evaporation, this decrease being determined by noting the amount of water or kerosene that must be added to fill the dish to the original level.

NOTE.—This test is relative only. That is, it is only suitable for comparing one varnish with another when the tests are made simultaneously under exactly the same conditions.

XII. TEST FOR NON-VOLATILE MATTER.

Procedure. 25. A portion of the sample shall be placed in a stoppered bottle or weighing pipette and weighed. About 1.5 g. of the sample shall be transferred to a weighed flat-bottom metal dish about 8 cm. (3.15 in.) in diameter, such as the cover of a friction-top tin can. The container shall again be weighed and the exact weight of the portion of the sample transferred to the weighed dish calculated by difference. The dish with its contents shall be heated for three hours in an oven maintained at 105 to 110° C. It shall then be weighed after cooling.

Non-Volatile Matter. 26. The ratio of the weight of the residue to that of the original sample expressed as a percentage shall be taken as the percentage of non-volatile matter in the varnish.

TENTATIVE METHODS OF TESTING ELECTRICAL PORCELAIN[1]

Serial Designation: D 116 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1921; REVISED, 1924.

Material Covered.

1. These tests are intended to apply to porcelain which is to be used for electrical insulating purposes.

I. TENSILE STRENGTH.

Apparatus.

2. Any standard testing machine may be employed, but it shall be of suitable capacity.

Preparation of Test Specimens.

3. Test specimens may be prepared by pugging or extruding rolls of suitable size, throwing rolls by hand or by cutting rolls from pugged blocks. For comparative tests one method of preparing specimens should be adhered to, as test specimens prepared by different processes show different results. They shall be turned in the green condition to such dimensions as will give fired pieces of standard size, shrinkage being determined and allowed for as in regular ceramic practice. Variation from the standard dimension shall be kept within ± 5 per cent, as it has been found that the strength per square inch calculated from results obtained with test specimens of about 0.2 sq. in. increases about 0.5 per cent for a decrease in area of 1 per cent.

Test specimens shall be fired in saggars on end, either on placing sand or clay bats. They shall not be buried in sand as this will cause the pieces to break in firing. Firing shall be carried out in the regular porcelain kilns. Specimens which have warped in firing shall be rejected because they will give unreliable results and therefore a sufficient number of specimens should be prepared to give the required number of satisfactory ones.

Specimens.

4. (*a*) *Ohio Brass Co. Method.*—The test specimens shall have the shape and dimensions shown in Fig. 1.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1925, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, Twenty-first St. and Clinton Ave., Irvington, N. J.

(*b*) *Jeffry-Dewitt Insulator Co. Method.*—The test specimens shall have the shape and dimensions shown in either Fig. 2 or Fig. 3. The maximum cross-section area in the reduced section of the specimen shall be not greater than 0.2 sq. in.

When dry, the shoulder of the specimens shall be glazed, leaving the reduced section free from glaze.

NOTE.—The glaze is necessary to obtain uniform results and insure that failure occurs in testing in the reduced section. The glaze is omitted from the reduced section in order to avoid variation in strength which may be attributable to the glaze.

Mounting of Specimens.

5. (*a*) *O.B. Method.*—The method of mounting the test specimen in the specimen holders is shown in Fig. 4. The method of using the assembly jig shown in the figure is as follows: The test specimen is calipered at the small section. The tapered jig, *G*, with the arbor, *E*, is then placed in the guides, *V*. The point on the tapered piece, *G*, which has the same diameter as the minimum section on the specimen is placed directly over the V-notched block, *N*. This piece is then raised until it comes in contact with the piece, *G*, and the wing nut, *S*, tightened. *E* and *G* are then removed and the cap pieces, *C*, screwed on to the rods, *R*, which are laid in the notches *V*-*V*. The center of the specimen is placed in the V-notched block, *N*, and the clamping piece, *L*, tightened down to hold it in place.

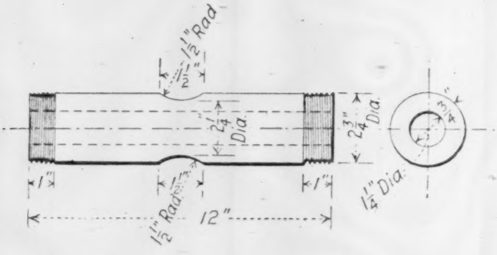

FIG. 1

One of the caps, *C*, with the attached rod, *R*, can then be moved over the end of the specimen and held in place by tightening the strap, *H*; the whole assembly apparatus is then stood on one end and the cap moved so as to allow filling with cement. The cap is then moved up in place, rotating it at the same time so as to properly work in the cement. The strap, *H*, is then tightened and the piece left undisturbed until the cement hardens.

When the cap has been attached at one end, the assembly apparatus can be stood on the other end and the other cap cemented in place.

NOTE.—This arrangement permits of setting up the jig properly and easily for specimens which vary slightly in diameter and insures keeping the center line of the specimen in the center line of the caps. A slight tip of the specimen will be unimportant so long as both caps can be assembled to the specimen.

After the cement has hardened (which will not require more than five or ten minutes if litharge cement is used), the specimen, can be removed and eyes screwed into caps in place of the rods, *R*.

(*b*) *J-D Method.*—The method of mounting the test specimen in this method of testing is as follows:

Test Specimen, Fig. 2 (Conical Ends).—The specimen shall be held by small steel clamps, Fig. 5, each consisting of a split bushing, *B*, ground to fit the test specimen, *T*, and held by a collar, *C*, the load being applied by the plate, P_1, held in slots of the jaws of the testing machine through the ball and socket joint, *J*. The soft gasket, *G*, of blotting paper shall be inserted between the porcelain and the bushing to distribute the load. A new gasket shall be used with each specimen.

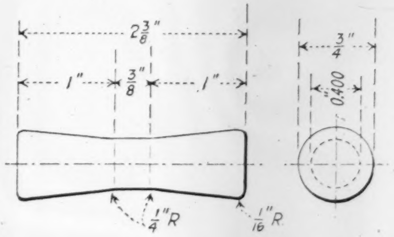

FIG. 2

Test Specimen, Fig. 3 (Dumb-bell Ends).—The specimen is held by a split ring, *R*, Fig. 6, with the same radius of curvature as the shoulders of the specimen. This ring fits into a recess in plate P_2 which, in turn, fits into the slots in the jaws of the testing machine.

NOTE.—No gasket is required with this piece when the shoulders are glazed, Satisfactory results have not been obtained with unglazed pieces, even when using a gasket. This form of specimen has the advantage of requiring no gasket and so is more rapid in manipulation and of allowing greater variation in dimensions.

Method.

6. (*a*) Not less than 10 specimens (preferably more) shall be tested in the normal condition.

(*b*) The specimen shall be pulled apart at such a constant speed that the beam of the testing machine can be kept well balanced at all loads.

(*c*) When failure occurs outside of the reduced section, that result shall be discarded.

(*d*) The tests shall be made at a room temperature of about 20° C. (68° F.).

Report. 7. The report shall include the following:

(*a*) The diameter in inches or centimeters as measured by a micrometer at the point of fracture.

(*b*) The breaking load of each specimen in pounds or in kilograms.

(*c*) The ultimate strength in pounds per square inch or in kilograms per square centimeter of each specimen as calculated from the actual area of the specimen measured at the point of fracture.

(*d*) The average of the results given in Paragraph (*c*).

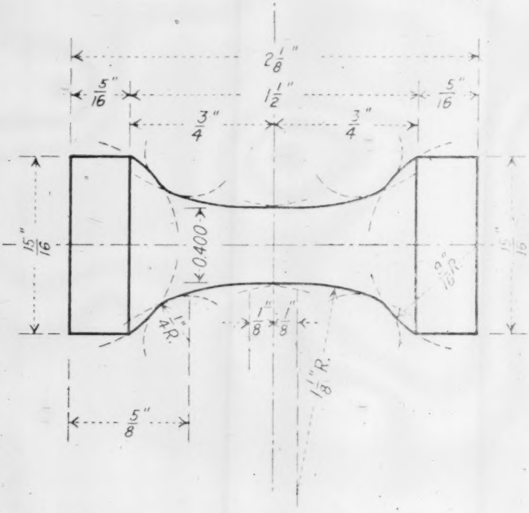

FIG. 3.

(*e*) The character of the material tested and a description of its behavior under stress.

(*f*) The speed in inches or centimeters per minute at which the jaws traveled during the test.

II. COMPRESSIVE STRENGTH.

Apparatus. 8. Any standard testing machine may be used. A contact pad or cushion of $\frac{1}{32}$ in. of blotting paper shall be placed between the upper and lower faces of the specimens and the heads of the testing machine to equalize irregularities in the surfaces. Fresh cushions shall be used for each specimen tested.

Specimens. 9. The test specimen shown in Fig. 7 shall be used for the compressive strength test.

Method.

10. (*a*) Not less than 10 specimens (preferably more) shall be tested in the condition in which they are received.

(*b*) The load shall be applied at that constant rate of speed which will permit the beam to be kept well balanced at all loads.

(*c*) The test shall be made at a room temperature of about 20° C. (68° F.).

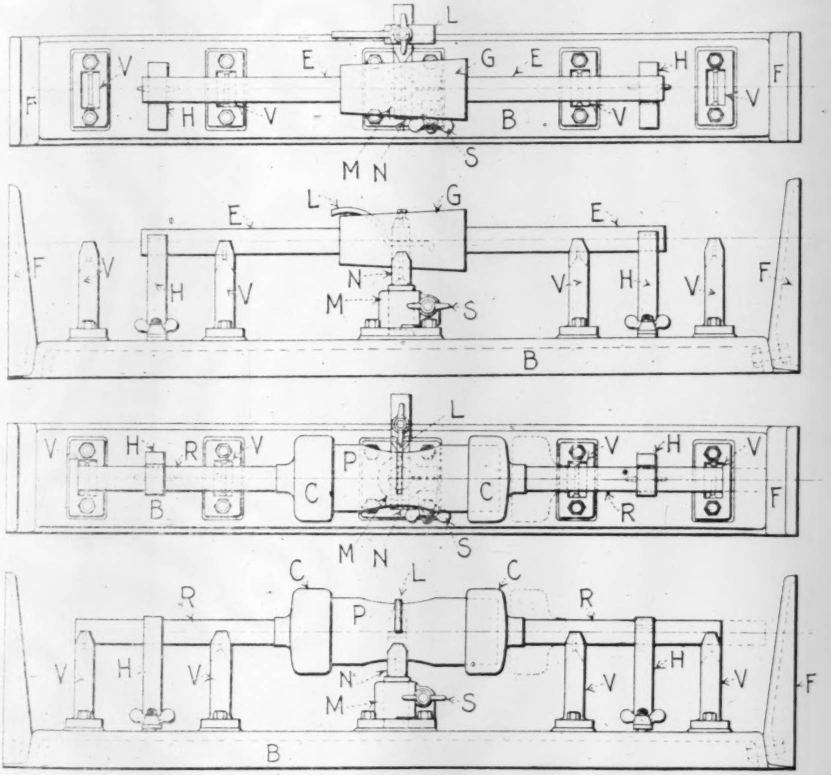

FIG. 4.

Report.

11. The report shall include the following:

(*a*) The dimensions of each specimen in inches or in millimeters.

(*b*) The load in pounds or kilograms on each specimen at the first sign of fracture.

(*c*) The ultimate compressive strength in pounds per square inch or in kilograms per square centimeter for each specimen calculated from the measured area before the load is applied.

(*d*) The average of the results given in Paragraph (*c*).

(*e*) General character of the material tested and a description of its behavior under load.

(*f*) The speed in inches or in centimeters at which the jaws traveled during the test.

III. RESISTANCE TO IMPACT.

Apparatus. 12. The test shall be made with an apparatus in which a weight of 1 lb. is raised $\frac{1}{2}$ in. and allowed to fall on the specimen. It is then raised 1 in. and allowed to fall again on the specimen. This is continued, the weight being raised and dropped through a distance increasing by increments of $\frac{1}{2}$ in. until the specimen is broken.

Specimen. 13. The test specimen shown in Fig. 7 shall be used for impact tests.

Procedure. 14. (*a*) The test specimen shall be clamped in the base of the impact tester directly under the hammer. The stops shall be set to give a successively increasing rise of hammer by $\frac{1}{2}$-in. increments, the first height being $\frac{1}{2}$ in.

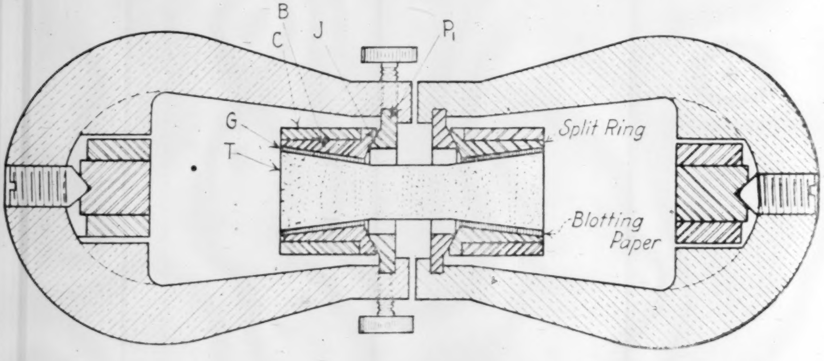

FIG. 5.

(*b*) The entire hammer shall weigh 1 lb.

(*c*) The test shall be continued until the specimen cracks.

(*d*) Not less than five specimens shall be tested in the condition in which they are received.

Report. 15. The report shall include the number of blows required to break each specimen, the energy of each blow in inch-pounds and the total energy in inch-pounds (that is, the sum of all blows).

NOTE.—The apparatus may be a simple hand-operated one constructed along the line of the one shown in Fig. 8 or a motor-operated machine where the weight is lifted and the distances are increased automatically.

IV. DIELECTRIC STRENGTH.

16. The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Insulating Materials (Serial Designation: D 48) of the American Society for Testing Materials.[1] **Apparatus.**

17. The specimens shall be as shown in Fig. 1 except that the threads may be omitted. **Specimens.**

18. (*a*) *Porcelain for all purposes.*—A pad of wet clay about $\frac{1}{4}$ in. thick shall be laid in the groove and a lining of wet clay about $\frac{1}{4}$ in. thick put on the inside of the specimen. The potential shall be applied to these two pads of clay by any suitable means. Mercury may be substituted for the wet clay if desired. The test should preferably be made in air but it may be made in transformer oil if necessary. **Method.**

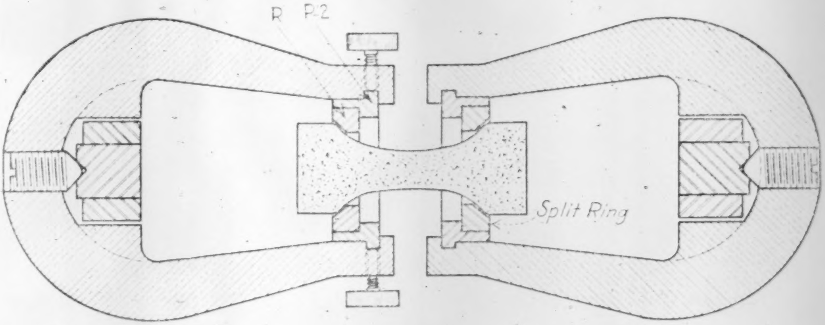

FIG. 6.

Not less than ten specimens shall be punctured in their normal condition at a normal room temperature of about 20° C. (68° F.).

(*b*) *Porcelain for transmission line insulators.*—In addition to the test prescribed in Paragraph (*a*), not less than 10 specimens shall be tested in the same manner at a temperature of 75° C. (167° F.).

(*c*) *Porcelain for spark plugs.*—In addition to the test prescribed in Paragraph (*a*), not less than 10 specimens shall be tested to determine the effect of high temperatures on the dielectric strength. The specimens shall be placed in an electrically heated oven the temperature of which can be raised at a constant rate to 600° C. (1112° F.). A given voltage shall be applied and maintained constant and the temperature raised at any constant rate such that the porcelain is always practically at the temperature of the air. The temperature shall be raised until puncture occurs.

(*d*) Whenever a puncture occurs at a point other than the minimum section of the specimen in any of the tests prescribed above, that result shall be discarded.

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[1] 1924 Book of A.S.T.M. Standards.

Report. 19. The report shall include the following:

(*a*) A statement of the purpose for which the porcelain is intended and the kind of tests which were made.

(*b*) The thickness of the specimen at the bottom of the groove.

(*c*) The voltage at puncture for each of the test specimens together with the average, maximum and mimimum volts per mil or per millimeter of thickness.

V. RESISTANCE TO THERMAL CHANGE.

(*A*) *Porcelain for Transmission Line Insulators.*

Apparatus. 20. The apparatus shall consist of a hot water bath maintained at a temperature of 100° C. (212° F.) and an ice water bath maintained at 0° C. (32° F.).

Specimens 21. The test specimens shall be as shown in Fig. 1.

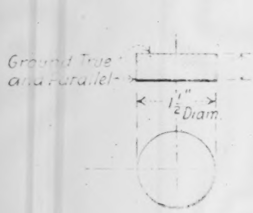

FIG. 7.

Method. 22. (*a*) The test specimen shall be immersed in the ice water bath for ten minutes and then transferred as quickly as possible to the hot water bath, and allowed to remain there for ten minutes. The specimen shall be transferred back to the cold water and the cycles continued until the specimen breaks.

(*b*) Not less than five specimens shall be tested.

Report. 23. Report the number of cycles necessary to cause fracture of each test specimen.

(*B*) *Porcelain for Spark Plugs and Heating Devices.*

Apparatus. 24. A furnace in which a temperature of 900° C. (1652° F.) can be obtained and any suitable testing machine for determining the transverse strength of small beams may be used.

Specimens 25. The specimens shall be as shown in Fig. 3.

Method. 26. (*a*) One-half of not less than 12 specimens shall be taken and placed in the furnace. The rate of heating shall be so adjusted that the temperature reaches 900° C. (1652° F.) in two hours. The furnace shall then be allowed to cool at such a rate that room temperature is reached in four hours.

(*b*) All specimens for transverse strength shall be tested by placing them on supports 6 in. apart and loading them at the center.

Report. 27. The report shall include the following:

(*a*) The load in pounds or kilograms required to break each specimen not subjected to heat treatment, together with the average.

(*b*) The load required to break each specimen that was subjected to heat treatment, together with the average.

(*c*) The percentage loss of strength due to heat treatment calculated from the two averages.

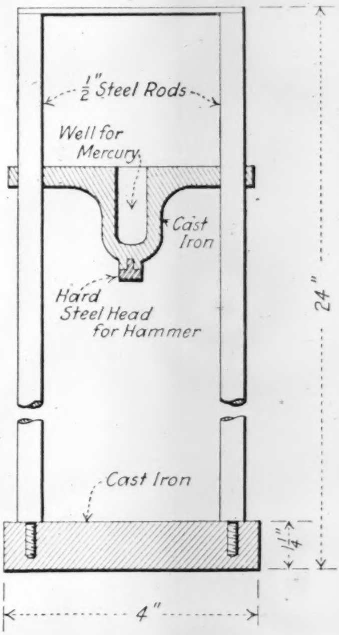

FIG. 8.

VI. POROSITY.

(*A*) *Water Absorption.*

28. Any good chemical balance, a beaker of distilled water at normal room temperature of about 20° C. (68° F.) and an oven of any standard make capable of maintaining a uniform temperature at the desired point within ± 5° C. shall be provided. **Apparatus.**

29. A single piece of porcelain shall be used weighing from 30 to 50 g. and with at least 50 per cent of the surface newly fractured. **Specimens.**

30. The specimen shall be dried for 24 hours at 120° C. (248° F.), cooled in a desiccator and weighed. The specimen shall then be totally submerged in the distilled water at room temperature (about 20° C.) and allowed to remain submerged for 100 hours. The water shall be boiled for approximately one hour during the first, twenty- **Method.**

fifth, forty-ninth and seventy-third hours. The specimen shall be removed at the end of the 100-hour period, the surface moisture carefully dried off with a clean, dry cloth and the specimen weighed.

Report. 31. The report shall include the following:

(*a*) The original weight of the specimen;

(*b*) The dry weight of the specimen;

(*c*) The dry weight of the specimen after immersion for 100 hours;

(*d*) The percentage of moisture content in each specimen as received and the percentage of moisture absorbed during 100 hours, taking the dry weight as 100 per cent, and the average where more than one specimen is tested.

(*B*) *Penetration of Dye.*

Apparatus. 32. A closed receptacle containing an alcoholic dye solution and a pump with which a pressure up to 600 lb. per sq. in. can be maintained in the receptable shall be provided.

Specimen. 33. A single specimen of porcelain shall be used, weighing at least 30 g. and with at least 50 per cent of the surface newly fractured. This specimen may be taken from any piece of finished ware, but if the piece varies materially in thickness (as, for example, in a transmission line insulator), a specimen shall be taken from both the thinnest and the thickest portions.

Method. 34. The specimen shall be immersed for two hours in a saturated methol alcoholic solution of eosin or fuchsine at a pressure of not less than 200 lb. per sq. in. nor more than 600 lb. per sq. in. at a room temperature of about 20° C. (68° F.).

Report. 35. The report shall include a statement of the maximum depth of penetration of the dye toward the interior of the specimen from the fractured surface exposed to the solution. (Lines of penetration along obvious cracks caused by possible fracturing are to be disregarded.)

TENTATIVE METHODS OF TESTING SHEET AND TAPE INSULATING MATERIALS FOR DIELECTRIC STRENGTH[1]

Serial Designation: D 149 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1922; REVISED, 1923, 1924

Scope.

1. These methods are designed to determine the dielectric strength of sheet and tape insulating materials. Since the dielectric strength of such materials is dependent upon the time of application of the electrical tension, two tests differing in time duration are included as *A*, Short-Time Dielectric Strength Test, and *B*, One-Minute Step-by-Step Dielectric Strength Test, respectively.

A third test, designated as an Endurance Dielectric Strength Test, is included under *C*. It shows the relative dielectric strength of different flexible sheet and tape insulating materials at high temperature when subjected to electrical tensions for relatively long periods.

It should be noted that the results obtained with the electrodes specified for sheet material will differ from those specified for tape material (Section 3) and will not be comparable because the apparent dielectric strength of thin materials varies with the area of the electrodes.

A. Short-Time Dielectric Strength Test

I. APPARATUS

High-Voltage Transformer.

2. (*a*) Any well-designed, high-tension transformer connected to an alternating current supply, having as nearly a true sine wave as possible, may be used. The transformer and the source of supply of energy shall be not less than 2 kva. for voltages of 50,000 volts or less, and not less than 5 kva. for voltages above 50,000 volts. The frequency shall not exceed 100 cycles per second.

(*b*) Regulation shall be so controlled that the high-tension testing voltage taken from the secondary of the testing transformer can be raised gradually from any point and in no case more than 500 volts at a step. The control may be made by generator field regulation, with an induction regulator, or with a variable ratio auto transformer. Any method of regulating the voltage is satisfactory which does not distort the wave more than 10 per cent from a sinusoidal shape.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, Twenty-first St. and Clinton Ave., Irvington, N. J.

(*c*) The voltage may be measured by any approved method which gives root-mean-square values, preferably by means of a voltmeter connected to a special voltmeter coil in the high-tension winding of the testing transformer, or to a separate step-down instrument potential transformer. A voltmeter on the low-tension side of the transformer is satisfactory, if the ratio of transformation does not change under any test condition. An electrostatic voltmeter properly calibrated in the high-tension circuit is also satisfactory. A spark gap may be used to check the readings at very high potentials.

(*d*) Some protection is desirable in the high-tension circuit of testing transformers where the potential is 25,000 volts or over, to prevent dangerous surges and limit the current when the test specimen is punctured. It is, however, desirable to have as much energy available as possible when puncture occurs. If impedance in the form of choke coils is used in series with the high-tension terminals, it should not be greater than that which will limit the high-tension current to double the normal rated current of the testing transformer.

When a spark gap is used, a non-inductive resistance of about one ohm per volt should be inserted in series with one terminal of the spark gap, to damp high-frequency oscillations at the time of breakdown and limit the current flow. This resistance shall be as near the gap as possible. If the test is made with one side grounded, this resistance shall be on the ungrounded side of the circuit, and if neither side is grounded, the resistance shall be inserted one-half on each side of the spark gap. Water tube resistors are preferable to carbon for this purpose, as carbon resistance may be materially decreased by the passage of current.

(*e*) The apparatus used and the method of measuring the voltage shall meet the requirements of the Standards of the American Institute of Electrical Engineers.

Electrodes. 3. The electrodes shall be of brass or copper with flat polished contact surfaces. For sheet material they shall be cylinders 2 in. (50.8 mm.) in diameter and 1 in. (25.4 mm.) in length with the edges rounded to a radius of $\frac{1}{4}$ in. (6.35 mm.). For tapes the electrodes shall be cylindrical rods $\frac{1}{4}$ in. (6.35 mm.) in diameter with edges rounded to a radius of $\frac{1}{32}$ in. (0.8 mm.) and the upper movable one shall weigh 0.1 lb. (45.4 g.) ± 0.005 lb. (2.3 g.).

II. TEST SPECIMENS

Test Specimens.

4. (*a*) The test specimens may be of any convenient size, but the total area of the specimens of one sample of material shall be sufficient to permit making at least ten satisfactory tests.

(*b*) The specimens shall be representative of the material to be tested, care being taken to select material which is free from abnormal defects such as blisters, wrinkles, cracks, etc.

III. PROCEDURE

Surrounding Medium.

5. The tests shall be made in air with the specimen at room temperature.

Condition of Electrodes.

6. The testing electrodes shall be kept clean and polished.

Position of Electrodes and Specimen.

7. The electrodes shall be self-aligning, and shall be placed exactly opposite one another with the specimen in a horizontal plane between them.

8. The edges of tapes shall be clamped between blocks of insulating material under a pressure of approximately 100 lb. per sq. in. to prevent flashover occurring before puncture.

NOTE.—In the Appendix are shown two different devices which have been found satisfactory for these tests.

Application of Voltage.

9. Starting at zero, the voltage shall be increased uniformly to breakdown at a rate of 0.5 kilovolt per second, except that if breakdown occurs at this rate in less than 40 seconds, the rate shall be decreased so that breakdown will occur in not less than 40 seconds. If the material fails at less than 5 kilovolts, the minimum time shall be reduced from 40 seconds to 20 seconds.

Number of Tests.

10. Ten tests shall be made and the average of these ten puncturing voltages shall be taken.

Thickness.

11. The thickness of the specimen shall be measured at each puncture, using a ratchet micrometer graduated to 0.001 in. and having a circular foot not less than 0.240 in. nor more than 0.260 in. in diameter.

Report.

12. The report shall include the following:

(*a*) The thickness of the specimen at each puncture;

(*b*) Total volts and volts per mil of thickness at each puncture;

(*c*) The average, maximum and minimum volts at puncture per mil of thickness for each sample;

(*d*) The room temperature;

(*e*) The relative humidity, in per cent;

(*f*) The duration of the test.

B. One-Minute Step-by-Step Dielectric Strength Test

IV. APPARATUS

Apparatus. 13. The apparatus shall consist of the high-voltage transformer and the electrodes specified in Sections 2 and 3.

V. TEST SPECIMENS

Test Specimens. 14. The test specimens shall be as specified in Section 4.

VI. PROCEDURE

Surrounding Medium. 15. The tests shall be made in air with the specimen at room temperature.

Condition of Electrodes. 16. The testing electrodes shall be kept clean and polished.

Position of Electrodes and Specimen. 17. The electrodes shall be self-aligning, and shall be placed exactly opposite one another with the specimen in a horizontal plane between them.

18. The edges of tapes shall be clamped between blocks of insulating material under a pressure of approximately 100 lb. per sq. in. to prevent flashover occurring before puncture.

NOTE.—In the Appendix are shown two different devices which have been found satisfactory for these tests.

Application of Voltage. 19. A voltage shall be applied which is equal to 40 per cent of the breakdown voltage obtained in the short-time test to the nearest even 1000 volts (or 500 volts with low voltages). The voltage shall then be increased by 10 per cent of the initial value until failure occurs, the voltage being held at each step for one minute. When changing from one step to a higher step, the voltage shall be increased to the reqiured value within 10 seconds.

Number of Tests. 20. Five tests shall be made and the average of these five puncturing voltages shall be taken.

Thickness. 21. The thickness of the specimen shall be measured at each puncture, using a ratchet micrometer graduated to 0.001 in. and having a circular foot not less than 0.240 in. nor more than 0.260 in. in diameter.

Report. 22. The report shall include the following:

(*a*) The thickness of the specimen at each puncture;

(*b*) Total volts and volts per mil of thickness at each puncture;

(*c*) The average, maximum and minimum volts at puncture per mil of thickness for each sample;

(*d*) The room temperature;

(*e*) The relative humidity, in per cent;

(*f*) The duration of the test;

(*g*) The value of the initially applied voltage and the value of the voltage at each step.

C. Endurance Dielectric Strength Test

VII. APPARATUS

Apparatus.

23. The apparatus shall consist of the high-voltage transformer specified in Section 2.

Test Specimen.

24. (*a*) The specimens shall be made by wrapping the material, in tape form with one-quarter lap, one-half lap, butt jointed or as sheets, on brass tubes. The tubes shall be, for sheets and for tape up to $1\frac{1}{2}$ in. in width, about 36 in. in length and 1 in. in outside diameter. For tapes wider than $1\frac{1}{2}$ in., the tubes shall be 2 in. in outside diameter. The sample shall be built up to the desired thickness, simulating practical conditions, winding all layers of tape in the same direction.

(*b*) A smooth layer of metal foil shall then be wrapped over the insulation for a distance of 24 in., leaving 6 in. of insulation uncovered at each end of the tube. The metal foil shall be bound in place with a wrapping of adhesive tape and shall extend the full length of the tube in order to protect the insulation at the end from corona discharge.

(*c*) A thermocouple shall be applied to the metal foil near the center of the tube and held in place by the adhesive tape.

VIII. PROCEDURE

Position of Specimen.

25. The specimen shall be mounted in an oven and a temperature of 100° C. (212° F.) maintained during the test. Provision shall be made for so mounting the specimen that the tube may be connected to the high voltage side of the circuit with the metal foil sheath and thermocouple connected to ground.

Application of Voltage.

26. A voltage equal to 10 per cent of the breakdown voltage (to the nearest kilovolt) obtained in the short-time test (Test *A*) shall be applied and maintained for 30 minutes. The voltage shall then be increased by steps of 20 per cent of the initial value until puncture occurs, the voltage being held at each step for 30 minutes.

Temperature Readings.

27. The temperature of the sample as indicated by the thermocouple shall be observed at intervals during the test and recorded at the end of each 30-minute period. It will be found that the temperature rises gradually until just before breakdown when the temperature increases rapidly. During this latter period, temperature readings shall be recorded at frequent intervals.

Report.

28. (*a*) The results shall be plotted using time, expressed in hours, as abscissas, and temperature, in degrees Centigrade, as ordinates. In addition to time as abscissas, the values of applied kilovolts shall be indicated since the value of kilovolts increases uniformly with

time. The significant values to be taken from the curve and reported are:

(1) Duration of test;
(2) Breakdown voltage;
(3) Temperature of specimen at breakdown;
(4) Rate of temperature rise during test.

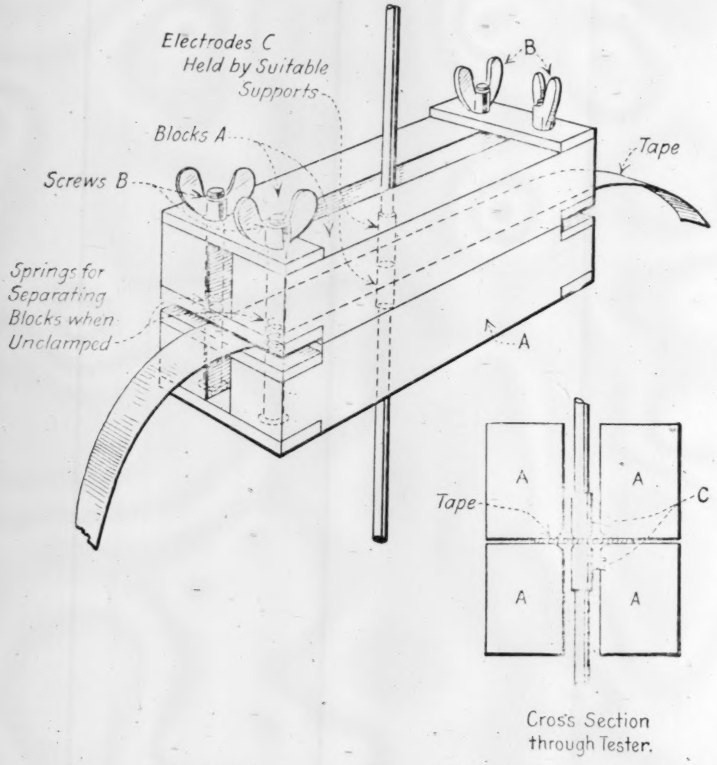
Electrodes C Held by Suitable Supports
B
Tape
Blocks A
Screws B
Springs for Separating Blocks when Unclamped
A
A
A
Tape
C
A
A
Cross Section through Tester.

FIG. 1.—Elementary Form of Tape Tester.

(*b*) The report shall also include a description of the specimen and its preparation, the thickness of the insulation and the number of layers of insulation.

APPENDIX

Referring to Fig. 1, the four wooden clamping blocks, *A*, are held together by the screws *B*. These blocks are impregnated with paraffin which assists in sealing the joints between the wooden blocks and the tape. The electrodes are introduced into the space between the blocks at *C*. The tape can be advanced through the blocks, for each shot, by opening and closing the clamping screws. In order to secure satisfactory results, the blocks must have accurately finished surfaces and should be carefully aligned.

Referring to Fig. 2, the two impregnated wooden clamping blocks, *A*, are pressed together by the spring, *B*, which is secured to the latched handle, *C*. Releasing the latch allows the blocks, *A*, to be separated to insert the tape or examine the electrodes or contact surfaces of the blocks.

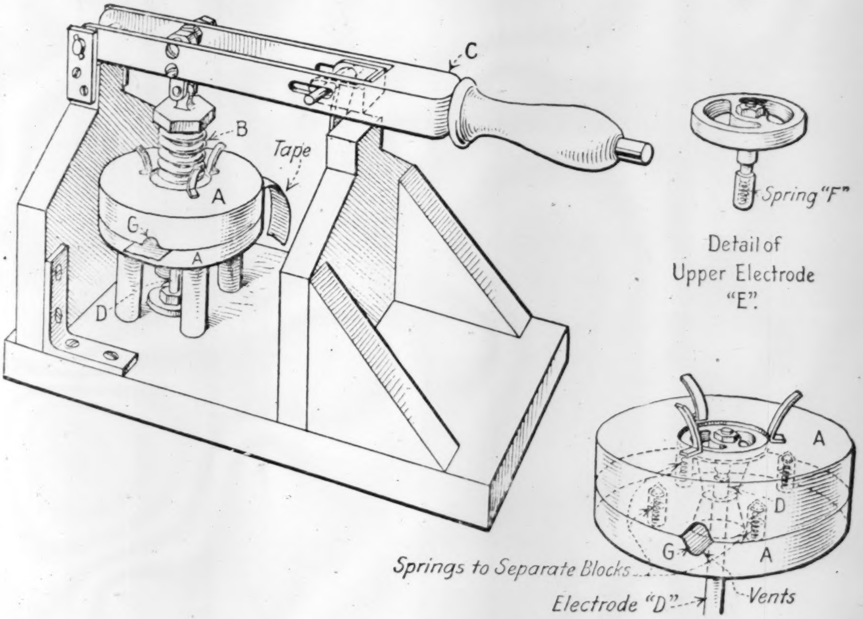

FIG. 2.—Lever-Operated Form of Tape Tester.

The lower electrode, *D*, is fixed in position with its top flush with the lower block *A*. The upper electrode, *E*, is removable and its contact face is pressed against the tape by the internal spring, *F*. The spring *B* seats on the electrode *E*, which rests on a shoulder in the block *A*.

The openings, *G*, provide the necessary vents for the arc which occurs when the tape under test fails. The successful operation of this device depends upon the accuracy of the contact faces of the blocks *A*, their alignment, the impregnation of the blocks *A* and the vent openings *G*.

TENTATIVE METHODS OF TESTING CABLE SPLICING AND POTHEAD COMPOUNDS[1]

Serial Designation: D 176 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

Issued, 1923; Revised, 1924.

Material Covered.

1. These tests are intended to cover compounds used in cable splices and potheads.

I. PHYSICAL TESTS

Physical Tests.

2. Each of the following tests shall be made in accordance with the method of test applicable, of the American Society for Testing Materials, as indicated:

(*a*) *Melting Point:* Tentative Method of Test for Melting Point of Petrolatum (Serial Designation: D 127 – 24 T).[2]

(*b*) *Softening Point,* for compounds having no definite melting point: Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (Serial Designation: D 36),[3] or

Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61).[3]

The method used should be indicated in the report.

(*c*) *Flash and Fire Points:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92).[3]

(*d*) *Evaporation:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6).[3]

(*e*) *Viscosity,* Temperature range from melting point to 150° C.: Saybolt Furol, Tentative Methods of Test for Viscosity of Petroleum Products and Lubricants (Serial Designation: D 88 – 24 T).[4]

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, Twenty-first St. and Clinton Ave., Irvington, N. J.

[2] See p. 872.

[3] 1924 Book of A.S.T.M. Standards.

[4] See p. 883.

(*f*) *Penetration Test*, Temperature range from melting or softening point to −25° C.: Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5).[1]

Brittleness. 3. To determine the brittleness of the material, the compound shall be spread on a piece of sheet metal in a layer $\frac{1}{16}$ in. in thickness. It shall then be submerged in water having a temperature at least 20° F. above the expected breaking point. It shall then be cooled 5° F. and held at this temperature for 5 minutes. The cooling shall then be continued in increments of 5° F. At each temperature interval the compounds shall be tested with the blade of a knife, inserting the point with the blade as nearly parallel with the sheet metal as is practicable, and pulling the compound from the sheet metal as rapidly as possible by rotating the blade about its back as an axis. The temperature at which the compound no longer stretches but snaps, shall be considered the breaking point.

II. DIELECTRIC STRENGTH TEST

Dielectric Strength. 4. (*a*) This test is intended to determine the dielectric strength of cable splicing and pothead compounds under voltage stresses of short duration. It is of value as a comparative test but does not indicate the permanent dielectric strength of these compounds.

(*b*) The dielectric strength of this class of material varies with the temperature. It is, therefore, recommended that a sufficient number of tests be made at different temperatures to establish the momentary dielectric strength - temperature curve from −25° C. to +100° C.

Sample. 5. A representative sample shall be taken from the original package, melted and poured directly into the testing container. Care should be used in melting and pouring the compound not to overheat it nor to entrap air. The electrodes should be heated to the approximate compound temperature before filling the container.

Electrodes. 6. The material shall be tested between hemispherical electrodes embedded therein which are $\frac{1}{2}$ in. in diameter separated by a gap of 0.1 in.

NOTE.—A convenient form of apparatus for holding the electrodes and compound is described in the Appendix.

Testing Transformer. Voltage Control and Measurement. 7. The testing transformer used, methods of voltage control and measurement shall be as outlined in Section 2 of the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (Serial Designation: D 149 - 24 T) of the American Society for Testing Materials.[2]

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[1] 1924 Book of A.S.T.M. Standards.

[2] See p. 1039.

Number of Specimens. 8. Five specimens at a given temperature shall be tested and the average value taken as the momentary dielectric strength of the compound at that temperature.

Report. 9. The report shall include the following:

(*a*) The momentary dielectric strength – temperature curve;

(*b*) The individual values of the puncturing voltage at the various temperatures.

III. COEFFICIENT OF EXPANSION

Apparatus. 10. Calibrated flasks of Pyrex or quartz glass holding approximately 250 cc. to the zero mark, having necks 1 cm. in internal diameter and graduated for 25 cc. in 0.1-cc. divisions, total capacity approximately 275 cc., shall be used.

NOTE.—If it is necessary to use a small sample, then a Cassia flask holding 100 cc., with neck graduated for 10 cc. in 0.1-cc. divisions, may be used.

11. The cylindrical oil bath for heating the sample shall be approximately 10 in. (25.4 cm.) in inside diameter and 20 in. (50.8 cm.) in inside depth with a false bottom 1 in. from the bottom and shall have provision for circulating the oil.

NOTE.—This bath may be made as follows: A shell about 10 in. (25.4 cm.) in inside diameter and 20 in. (50.8 cm.) in inside depth is electrically heated by winding the shell with resistance wire and covering with five layers of asbestos paper. A motor-driven paddle at the bottom will give effective oil circulation.

12. A lead collar to be hung on the flask during test to prevent the oil currents of the bath from moving the flask.

Calibration. 13. The capacity of the flask at the zero point and several points on the scale shall be determined by filling the flask with distilled water at a known temperature and weighing.

Procedure. 14. The flask shall first be warmed slightly, then partly filled with melted compound and placed in the bath which shall then be brought to the highest temperature of the range over which the test is to extend. The flask shall then be filled to within the last cc. marked on the neck. The bath shall be held at this temperature for not less than 30 minutes (principally to remove air bubbles) and the whole shall then be slowly cooled to room temperature (10 to 12 hours). Before starting the test, the flasks shall be examined for the the presence of cavities or irregular contraction of the compound. Some compounds, after cooling below the liquid state, tend to stick to the sides of the neck of the flask. In that case it is necessary to gradually warm the neck and flow the compound to meet the rest, after which the flask is placed in the bath for an hour or so to insure equalizing the temperature.

With the compound satisfactorily placed in the flasks at the lowest temperature, the height of the column in the neck shall be read and the bath then slowly heated. Readings shall be taken at 5° C. intervals, holding the bath as constant as possible at each point until no more expansion occurs at that point, the procedure being repeated for each point until maximum temperature is reached.

Precautions.

15. During the test, temperature readings shall be taken at top and bottom of the bath to detect any variation.

Until the compound is completely liquefied, intervals between readings should be three to four hours, especially between 35 and 55° C.

After becoming liquefied, the time necessary for obtaining a reading may be reduced to about 30 minutes.

Report.

16. (*a*) After securing the readings over the temperature range desired, a curve shall be plotted from the temperature and flask readings from which the coefficient of expansion shall be calculated from the formula:

$$\frac{V_1 - V}{(T_1 - T)\,V} + C$$

where V = original volume;
V_1 = volume at higher temperature;
T = original temperature;
T_1 = higher temperature;
C = constant = coefficient of expansion of glass container.

(*b*) The coefficient shall be calculated for three ranges as follows:

(1) From the minimum temperature at which the measurement was made to 10° C. below the melting point. This is intended to give the average coefficient for the solid condition.

(2) From 5° C. above the melting point to 100° C. This is intended to give the average coefficient for the liquid condition.

(3) From the minimum temperature at which a measurement was made to 100° C.

In reporting the coefficient of expansion the corresponding temperature range shall be indicated in each case.

APPENDIX

Because of the great difficulty in removing most cable splicing and pot head compounds from the container and from the electrodes, an arrangement was devised sufficiently inexpensive to permit of its being discarded wholly or in part after the test. That is, each specimen with its container can be entirely discarded without undue expense.

One form of container consists of a small rectangular box about 2½ in. (6.4 cm.) in length and 1½ in. (3.8 cm.) square, the ends of which are dry wood about ¼ in. in thickness. The sides and bottom are formed from a piece of thin, hard fiber tacked to the wooden end pieces. The fiber is partially cut at the corners which permits making a sharp, square bend.

Each electrode is mounted on the end of a piece of straight copper wire, No. 10 A.W.G., which passes through a hole at the center of the wooden end pieces. These holes are drilled in one operation so that they are in the same straight line. They are made slightly smaller so that the rods fit tightly and are therefore not readily moved.

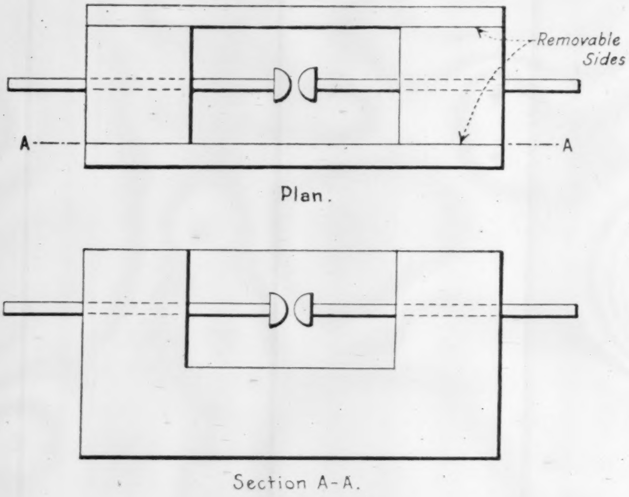

FIG. 1.—Container, Showing Electrodes in Place for Dielectric Test of Cable Splicing and Pothead Compounds.

Fig. 1 shows a sketch of a container in which the ends and the bottom are formed from one block of thoroughly dried wood which has been boiled in paraffin, the sides being pieces of thin, hard fiber tacked to the wood.

In the construction of these containers, it is obviously important that the electrodes be reasonably co-axial and that the gap remain constant.

In making tests at high voltage it will probably be found necessary to immerse the container with its specimen in oil in order to prevent flash-over between the exposed ends of the electrode rods. The ends of the rods can be bent to form hooks, by means of which the specimen holder can be readily suspended in a jar of oil.

TENTATIVE METHODS OF TESTING UNTREATED INSULATING PAPER[1]

Serial Designation: D 202 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Material Covered.

1. These methods apply to untreated paper which is to be used as an electrical insulator or as a constituent of a composite material used for electrical insulating purposes.

I. SAMPLING

Sampling.

2. (*a*) From shipments consisting of rolls, a sample of at least 1 sq. yd. in area, cut across the entire width of the roll, shall be taken from every tenth roll in the shipment. From other shipments such as sheets or pads of tape, samples of equivalent area shall be taken in such a manner as to be equally representative of the shipment. In no case shall less than three samples be taken.

NOTE.—It is recommended that several turns of paper from each roll sampled be torn off and discarded before the samples are taken.

(*b*) The tests for physical properties shall be made upon each sample.

(*c*) The tests for acidity,[2] moisture content, size,[2] ash and for identification of fibers[2] shall be made in duplicate upon portions taken from a composite sample. This composite sample shall be made up of a sufficient number of small pieces, each of approximately 6.5 sq.cm. (1 sq. in.) in area taken in nearly equal amounts from each of the samples taken in accordance with Paragraph (*a*).

(*d*) The required number of samples shall be taken at equal intervals across the sheet, the two end samples being taken at the edges of the sheet after removing any damaged paper. When it is not possible to secure the required number of specimens in this manner in going once across the sheet, the selection across the sheet shall be repeated as many times as necessary until the required number of specimens is secured.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, Twenty-first St. and Clinton Ave., Irvington, N. J.

[2] The tests for acidity, size, identification of fibers, folding endurance and air permeability do not appear in these methods but will be included as soon as the tests are developed by the committee.

II. CONDITIONING SAMPLES

Conditioning 3. Samples shall be conditioned in air maintained at a relative humidity between 60 and 65 per cent as measured with a sling psychrometer or its equivalent. The temperature of the air shall be maintained as constant as possible at some temperature between the limits of 20 and 30° C. (68 and 86° F.). The samples should remain in the conditioned air for not less than 4 hours prior to the tests and should be supported so as to allow a free circulation around each sample. The following physical tests shall be made in the conditioned air: tensile breaking strength, tearing strength, bursting strength, folding endurance,[1] air permeability,[1] and thickness.

III. MOISTURE CONTENT

Apparatus. 4. A weighing bottle, evaporating dish, thermometer, constant-temperature oven, chemical balance and desiccator are necessary for the test. The weighing bottle should be of convenient size, about 65 mm. (2.56 in.) in height and 45 mm. (1.77 in.) in diameter with a wide mouth provided with a ground-glass stopper. The chemical balance should be sensitive to 0.1 mg.

Specimen. 5. The moisture content figure is used to calculate the percentage of acidity, size, and ash of the paper to the bone-dry basis. It shall be determined on 2 to 5-g. samples selected in accordance with Section 2 (*c*).

If the moisture content of the paper as received at the purchaser's works is desired or at any other stated time, it shall be made on the sample taken at the definitely stated time by cutting small pieces of approximately 6.5 sq. cm. (1 sq. in.) in area from the required number of rolls or pads of tape in accordance with Section 2 (*a*) and immediately placed into an air-tight container.

NOTE.—Since paper adjusts itself, as regards moisture content, to the humidity of the surrounding atmosphere in a very short time (2 or 3 minutes), special care must be exercised to transfer rapidly the sample from the roll or bundle to the container and from the container to the weighing bottle.

Procedure. 6. The sample before drying shall be weighed in the tared bottle with the stopper in place. The bottle shall then be placed in the oven at 100 to 105° C. (212 to 221° F.), the stopper removed and laid alongside of the bottle and the contents transferred to the drying dish. After one hour, while still in the oven, the sample shall be replaced in the weighing bottle, and the bottle stoppered and transferred to the desiccator. The stopper should be removed while the bottle cools. When the specimen and the bottle have cooled to room temperature, the stopper shall be replaced and the bottle with its contents weighed. This process shall be repeated at intervals of one hour until the difference in weight between two successive weighings is not more than 0.2 per cent of the weight of the specimen.

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[1] The tests for acidity, size, identification of fibers, folding endurance and air permeability do not appear in these methods but will be included as soon as the tests are developed by the committee.

NOTE.—The weighing bottle or sample should not be touched with the fingers during this test.

Report. 7. The moisture content shall be expressed (1) as a percentage of the weight of the dry sample, and (2) as a percentage of the weight of the undried sample.

IV. THICKNESS

Apparatus. 8. A micrometer of the spring actuated, dial type shall be used. The plunger shall be capable of being raised by the application of an upward pressure to it. The plunger surface shall be circular in shape and 12.7 mm. (0.50 in.) in diameter.

In addition to these requirements, the instrument shall conform to the following:

(*a*) The pressure applied to the plunger necessary to move the pointer from zero to a positive reading shall be not greater than 1135 g. (40 oz.).

(*b*) The pressure applied to the plunger necessary to just prevent movement of the pointer from zero to a lower reading shall be not less than 455 g. (16 oz.).

(*c*) If the instrument is provided with a device for controlling the speed of descent of the plunger, the latter shall not strike the anvil with an impact pressure greater than 1135 g. (40 oz.).

(*d*) The diameter of the dial shall be approximately 15 cm. (6 in.) and shall be graduated preferably in divisions indicating a thickness of 0.0127 mm. (0.0005 in.) and in no case greater than 0.0254 mm. (0.001 in.). Graduations indicating a thickness of 0.0254 mm. (0.001 in.) shall be at least 3 mm. (0.12 in.) apart.

(*e*) Measurements made on standard steel thickness gages shall be within the following tolerances:

INTERVALS	PERMISSIBLE DEVIATION OF READING FROM ACTUAL THICKNESS OF STANDARD STEEL GAGE
0 to 0.25 mm. (0 to 0.01 in.) incl.	±0.0025 mm. (0.0001 in.)
Over 0.25 mm. to 1.02 mm. (0.01 in. to 0.04 in.) incl.	±0.0051 mm. (0.0002 in.)
Over 1.02 mm. to 3.05 mm. (0.04 in. to 0.12 in.) incl.	±0.0102 mm. (0.0004 in.)

(*f*) Convenient means shall be provided for setting the pointer to the zero position.

(*g*) The micrometer shall be tested periodically as outlined above and if it does not conform to these requirements its mechanism should be readjusted.

Specimens. 9. Specimens shall consist of the original samples obtained in accordance with Section 2 (*a*).

Methods. 10. At least five readings shall be taken at regular intervals across the entire width of each specimen. When measuring paper less than 0.05 mm. (0.002 in.) in thickness, a sufficient number of layers to give a reading on the scale of not less than 0.13 mm. (0.005 in.) shall be used.

Report. 11. The average, maximum and minimum thicknesses obtained on each specimen shall be reported.

V. TENSILE BREAKING STRENGTH

Apparatus. 12. (*a*) A testing machine suitably designed for testing paper shall be used. The machine shall preferably be power driven.

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.).

(*c*) The machine shall be graduated to read 0.45 kg. (1 lb.) or 1 kg. (2.2 lb.) or less per scale division for testing paper breaking at 22.7 kg. (50 lb.) or over, and to 0.23 kg. (0.5 lb.) or 0.5 kg. (1.1 lb.) or less for testing paper breaking under 22.7 kg. (50 lb.).

Specimens 13. From each of the samples selected in accordance with Section 2 (*a*), specimens shall be cut at least ten in the machine direction and if practicable, ten in the cross-machine direction. The specimens shall not exceed 2.54 cm. (1 in.) in width and shall be 25.4 cm. (10 in.) in length with clean-cut edges.

Procedure. 14. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall be not less than 5:1 nor more than 10:1.

(*b*) The rate of travel of the movable jaw shall be constant. It shall preferably be 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the paper breaks at or in the jaws shall be rejected.

Report. 15. (*a*) The results of the machine-direction specimens and the cross-machine-direction specimens shall be reported separately.

(*b*) The results shall be reported in kilograms or pounds together with the width of the specimen in centimeters or inches and also the average thickness.

(*c*) The maximum, minimum, and average breaking load shall be reported for the machine-direction and the cross-machine direction.

VI. TEARING STRENGTH

16. The testing machine shall be of the pendulum impulse type so designed as to produce a tear approximately 4.2 cm. (1.66 in.) long. The knife mounted on the machine to cut the slit for the tear shall be maintained sharp. **Apparatus.**

17. The specimens shall be taken from the original samples obtained in accordance with Section 2 (*b*) and shall be cut 6.3 cm. (2.5 in.) in width and at least 6.3 cm. (2.5 in.) in length. Enough specimens shall be cut so that at least five readings in the machine direction and five readings in the cross-direction, if possible, can be obtained for each original sample. **Specimen.**

18. Enough paper shall be torn so that the readings on the machine shall be not less than 10 nor more than 20 g., unless one paper alone yields a reading greater than 20 g., in which case only one paper shall be torn at one time. Readings obtained when a tear deviates more than 6.3 mm. (0.25 in.) from a straight line, shall be rejected. The readings obtained shall be multiplied by the instrument constant corresponding to the number of sheets torn. **Method.**

19. (*a*) The tearing strengths obtained on the machine-direction specimens and on the cross-direction specimens shall be reported separately in grams. **Report.**

(*b*) The average, the maximum, and the minimum tearing strengths shall be reported for the machine-direction specimens. If possible, similar results shall be reported for the cross-direction specimens.

VII. BURSTING STRENGTH

20. The testing machine shall have a circular flexible diaphragm 6.44 sq. cm. (1 sq. in.) in area. The pressure chamber shall be filled with glycerin or other suitable pressure medium and shall contain no air spaces. The test specimen shall be held in position over the diaphragm in a clamp having a circular hole approximately 6.44 sq. cm. (1 sq. in.) in area so that the diaphragm will force the paper into the hole when pressure is applied under the diaphragm. The pressure exerted on the diaphragm shall be indicated on a dial, graduated to at least 0.23 kg. (0.5 lb.) for papers giving bursting strengths 18 kg. (40 lb.) or under. A dial graduated 0.45 kg. (1 lb.) may be used in testing papers which give higher bursting strengths. The machine may be either hand-operated or power-driven, the latter being preferable. **Apparatus.**

21. If practicable, the specimen shall be so cut from the stock as to permit ten bursting tests on a line across the sheet or roll. **Specimen.**

Procedure. 22. Ten bursts shall be made. The testing machine shall be driven at a uniform speed of 120 r.p.m. until the specimen bursts.

Report. 23. The report shall include the average, the maximum, and the minimum results obtained.

VIII. ABSORPTION

(RISE OF WATER)

Apparatus. 24. A suitable container and support for specimens and scale is shown in Fig. 1.

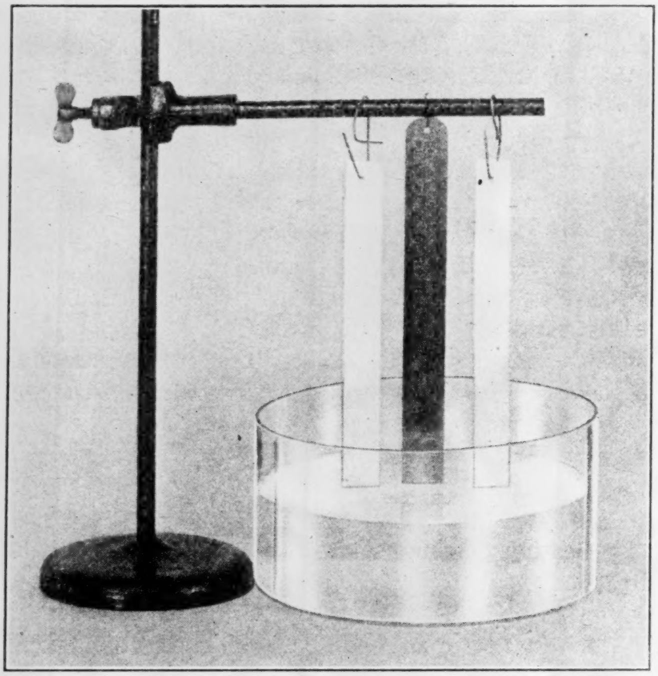

FIG. 1.—Apparatus for Absorption Test.

Specimens. 25. Ten strips 2.5 cm. (1 in.) in width and at least 12.5 cm. (5 in.) in length shall be cut from the samples obtained in accordance with Section 2 (*a*), five being cut parallel with the machine direction of the paper and five being cut parallel with the cross-direction of the paper.

Procedure. 26. The specimens shall be suspended vertically with one end dipping 3.2 mm. (0.125 in.) in distilled water at room temperature.

After five minutes of suspension, the rise of the water in the paper above the water level shall be noted. The rise may be measured by reading directly from the scale the height of absorption.

Report. 27. The rise of water shall be reported in millimeters, to the nearest 3 mm. or in inches to the nearest $\frac{1}{8}$ in.

IX. MIL WEIGHT PER REAM

(APPARENT DENSITY)

Apparatus. 28. A scale, sharp knife, chemical balance and weighing bottle are necessary for the test.

Specimens. 29. Duplicate specimens shall be taken from as widely separated portions as possible from each of the samples obtained in accordance with Section 2 (*a*) and conditioned in accordance with Section 3.

Procedure. 30. (*a*) Each specimen while in the conditioned atmosphere (see Section 3) shall be cut accurately to any convenient size, for example, 232.3 sq. cm. (36 sq. in.) in area, and accurately weighed. Specimens of sufficient size to weigh at least from 3 to 5 g. (0.11 to 0.18 oz.) should be taken. If it is not possible to do the weighing in the conditioned atmosphere, the specimen shall be placed in a weighing bottle and tightly stoppered with a ground glass stopper before being removed from the conditioned atmosphere. The thickness of each specimen shall be determined in accordance with Section 10.

(*b*) *Mil Weight per Ream of Any Size.*—The mil (or point) weight in pounds per ream of any size may be calculated from the following formula:

$$W = 0.002205\,\frac{mSN}{ta}$$

where m = the weight of the specimen expressed in grams;
t = the average thickness of the specimen expressed in mils (thousandths of an inch);
a = the area of the specimen expressed in square inches;
S = the area of one sheet in the basic ream expressed in square inches;
N = the number of sheets in the ream.

NOTE.—0.002205 is contracted from 0.00220462.

NOTE.—The following formulas may be used to calculate the mil weight in pounds per ream for reams of particular sizes, provided a specimen of exactly 232.3 sq. cm. (36 sq. in.) is used:

Ream of 24 by 36 in., 480 sheets.

$$W = 25.40\,\frac{m}{t}$$

where m = the weight of specimen expressed in grams;
t = the average thickness of the specimen in mils (thousandths of an inch).

25.40 is contracted from 25.3972224.

Ream of 24 by 36 in., 500 sheets.

$$W = 26.45 \frac{m}{t}$$

where m and t are the same as above and 26.45 is contracted from 26.45544.

NOTE.—The ream weight may be obtained from the above formulas by omitting the thickness "t".

(*c*) *Weight per Unit Volume.*—The weight in pounds per cubic foot (density) may be calculated from the following formula:

$$D = 3810 \frac{m}{ta}$$

Where m = the weight of the specimen expressed in grams.
t = the average thickness of the specimen expressed in mils (thousandths of an inch).
a = the area of the specimen expressed in square inches.

NOTE.—3810 is contracted from 3809.58336.

NOTE.—To convert weight in pounds per cubic foot to mil weight in pounds per ream of 24 by 36 in., 480 sheets, multiply by 0.24; to convert to mil weight in pounds per ream of 24 by 36 in., 500 sheets, multiply by 0.25.

Report. 31. The weight in pounds per cubic foot or the mil weight per ream shall be reported. The size of the ream must be given when the mil weight per ream is reported.

X. ASH

Apparatus. 32. A suitable crucible such as platinum, nickel or porcelain, a balance sensitive to 0.1 mg., and a desiccator are necessary for the test.

Specimen. 33. Not less than 2 g. of dry, finely-divided paper from the "moisture determination" sample as obtained in accordance with Section 6 shall be used.

Procedure. 34. The sample shall be transferred rapidly from the weighing bottle containing the dried sample into the crucible. The weighing bottle shall immediately be re-stoppered and re-weighed, and the exact weight of the sample obtained by taking the difference in weights of the weighing bottle and the sample. The sample shall be completely ignited in the crucible, preferably in a muffle furnace, all precautions being taken to prevent loss of ash or sample. The residue of incombustible mineral matter (ash) shall be desiccated, cooled and weighed, and the amount computed as a percentage of the weight of the dried sample.

Report. 35. The amount of ash shall be reported as a percentage of the weight of the dry sample (see Section 7 (*a*)) and also as a percentage of the weight of the undried sample (see Section 7 (*b*)).

TENTATIVE SPECIFICATIONS
FOR
STEAM HOSE[1]

Serial Designation: D 54 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1921; REVISED, 1924

Material Covered. 1. These specifications cover wrapped fabric steam hose suitable for steam connections when the steam pressure does not exceed 125 lb. per sq. in.

I. MANUFACTURE

Construction. 2. The hose shall consist of:

(*a*) An inner rubber tube;

(*b*) Cotton duck reinforcement;

(*c*) An outer rubber cover;

(*d*) A protective covering of wire armor when specified.

Rubber Tube. 3. The inner rubber tube shall be smooth, uniform in quality and thickness, and free from injurious defects.

TABLE I.—NUMBER OF PLIES

INSIDE DIAMETER OF HOSE, IN.	NUMBER OF PLIES
$\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$	4
1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{5}{8}$	5
$1\frac{3}{4}$	6
2	8

Cotton Reinforcement. 4. (*a*) The reinforcement shall consist of plies of cotton duck cut on the bias and applied evenly and firmly over the tube with not less than a $\frac{1}{2}$-in. lap, not sewed. The number of plies shall be as specified in Table I. The plies of duck shall be well frictioned on both sides with a rubber compound which shall firmly join the plies to the rubber tube and cover and to each other.

(*b*) The cotton duck shall be evenly woven from high-grade cotton and shall be free from mechanical defects.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Steam Hose. The Standard Specifications, which were last published under the Serial Designation: D 54 - 20, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. H. Grafton, Secretary of Committee D-11 on Rubber Products, Quaker City Rubber Co., Wissinoming, Philadelphia, Pa.

(*c*) The reinforcements shall be sufficiently strong to enable the hose to successfully withstand the prescribed hydrostatic pressure test, yet at the same time be soft and pliable.

Rubber Cover. 5. The rubber cover shall be uniform in quality and thickness, and free from injurious defects.

Wire Armor. 6. The wire for wire-wound hose shall be galvanized steel, half-round or elliptical, $\frac{7}{32}$ in. in diameter, wound tightly around the outside of the hose with a pitch of 1 in.

II. PHYSICAL PROPERTIES AND TESTS

Standard Methods. 7. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the Standard Methods of Testing Rubber Products (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Test Samples. 8. (*a*) Two samples, each 24 in. in length, shall be taken from each lot of 500 ft. or less of each size of long-length hose and from each lot of 200 pieces or less of car-heating steam hose. One of these samples shall be used for hydrostatic tests and the other for the physical and steam tests.

(*b*) A portion of sufficient length shall be cut from one of the samples and subjected to tension, elongation and friction tests. The remaining portion of the sample shall be used for the steam tests.

Tests of Tube and Cover. 9. (*a*) In the case of hose 1 in. or less in diameter, the test specimens shall be cut longitudinally from the sample of hose; in the case of hose over 1 in. in diameter the test specimens shall be cut transversely.

(*b*) The tensile strength and elongation of the tube and cover shall not be less than the following values:

	BEFORE STEAM TEST	AFTER STEAM TEST
Tensile strength of tube.......	750 lb. per sq. in.	550 lb. per sq. in.
Tensile strength of cover......	600 lb. per sq. in.	450 lb. per sq. in.
Elongation at rupture.........	2 in. to 6 in.	2 in to 4 in.

Friction Tests. 10. The adhesion between plies, between the cover and the plies, and between the tube and the plies shall be such that the weights specified below will not cause a separation at a rate greater than 1 in. per minute:

	WEIGHT, LB.	
	BEFORE STEAM TEST	AFTER STEAM TEST
Between plies of duck......................	18	15
Between duck and tube......................	15	12
Between duck and cover......................	15	12

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[1] 1924 Book of A.S.T.M. Standards.

Maximum Deterioration after Steam Test.

11. After the steam test, the tensile strength and elongation of the tube and cover shall not be less than the values specified in Section 9 (*b*). Furthermore, for the tube these values shall not be more than 50 per cent less than the values obtained before steaming and for the cover not more than 60 per cent less than the values obtained before steaming.

Steam Test.

12. (*a*) The rack steam test shall be used. The test length described in Section 8 (*b*) shall be connected to a rack and dry saturated steam at an average pressure of 75 lb. per sq. in. ±3 lb. shall be allowed to pass through the hose continuously for two periods of seven hours each. Between the first and second periods and between the second period and the time of testing, the hose shall be permitted to rest not less than 12 nor more than 18 hours.

(*b*) The hose upon examination immediately after its removal from the rack shall disclose no blistering of the tube or loosening of the tube from the fabric nor shall the inside diameter be more than 15 per cent greater than the original diameter.

TABLE II.—HYDROSTATIC TEST PRESSURES

INSIDE DIAMETER OF HOSE, IN.	TEST PRESSURES, LB. PER SQ. IN.
$\frac{3}{8}$, $\frac{1}{2}$	800
$\frac{3}{4}$	750
1	750
$1\frac{1}{4}$	750
$1\frac{1}{2}$	650
$1\frac{5}{8}$	650
$1\frac{3}{4}$	650
2	550

Hydrostatic Tests.

13. The 24-in. section selected as described in Section 8 (*a*) shall be subjected to a hydrostatic test and shall not burst at a lower pressure than that specified in Table II for hose of its size.

III. SIZES AND DIMENSIONS

Sizes and Dimensions.

14. (*a*) The hose shall be in accordance with the size and length specified by the purchaser.

(*b*) The thickness of the cover shall not be less than $\frac{1}{16}$ in. The thickness of the tube shall not be less than $\frac{1}{8}$ in.

(*c*) The diameters of the hose shall be in accordance with Table III. The inside diameter shall not vary more than $\pm\frac{1}{32}$ in. and the outside diameter not more than $\pm\frac{1}{16}$ in. from the values given.

IV. MARKING

Marking.

15. (*a*) Each 50-ft. length of hose shall have inlaid in rubber in three places, namely, midway between the ends and within 10 ft. of each end, a brand showing the name of the manufacturer, the month and year of manufacture, the trade name of the hose, and the legend

"A.S.T.M. Specifications." In addition, each brand shall bear a serial number for each lot of 500 ft. or less of each size of long-length hose and for each lot of 200 pieces or less of car-heating steam hose, the serial number to begin with 1 on the first of each year and continue consecutively until the end of the year. Lengths shorter than 50 ft. shall have only one brand similar to the above at a point near the center of the length. The letters and figures shall be at least $\frac{1}{4}$ in. high, shall stand $\frac{1}{32}$ in. in relief, and shall be clear and distinct.

(*b*) Serial numbers of rejected hose shall not be applied to any other hose during the same calendar year.

V. INSPECTION AND REJECTION

Inspection. 16. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection.

TABLE III.—DIAMETERS

Nominal Inside Diameter, in.	Nominal Outside Diameter, in.
$\frac{3}{8}$	1
$\frac{1}{2}$	$1\frac{1}{8}$
$\frac{3}{4}$	$1\frac{1}{2}$
1	$1\frac{13}{16}$
$1\frac{1}{4}$	$2\frac{1}{16}$
$1\frac{1}{2}$	$2\frac{5}{16}$
$1\frac{5}{8}$	$2\frac{7}{16}$
$1\frac{3}{4}$	$2\frac{5}{8}$
2	$3\frac{1}{16}$

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. But such tests shall be made within 60 days after receipt of the shipment and at the expense of the purchaser.

Rejection. 17. (*a*) Each length of hose which fails to meet any of the requirements of these specifications shall be rejected.

(*b*) In the case of failure to pass any one of the tests specified in Sections 9 to 13, inclusive, the entire lot of hose represented by the sample, or samples, subjected to these tests, shall be rejected.

Rehearing. 18. Samples of rejected hose shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

TOLERANCES FOR HOSE DUCKS AND BELT DUCKS[1]

Serial Designation: D 181 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

Issued, 1923; Revised, 1924.

Tolerances.

1. Tolerances shall be the limit within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract. They may be classified as the allowable limits of the quantitative characteristics of the fabric as defined in the specifications. The following tolerances are based upon the Standard Methods of Testing Cotton Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[2]

I. WIDTH

Hose Ducks.

2. *Hose Ducks*, ranging in width from 40 to 72 in. inclusive:

(*a*) No individual measurement made to determine the width of the fabric shall be more than 2 per cent over or under the specified average width.

(*b*) The average width determined by measurements shall be not more than 1½ per cent over or under the specified average width.

Rubber and Balata Ducks.

3. *Rubber and Balata Belt Ducks*, ranging in width from 42 to 72 in., inclusive:

(*a*) No individual measurement made to determine the width of the fabric shall be more than 1½ per cent over or under the specified average width.

(*b*) The average width determined by measurements shall be not more than 1 per cent over or under the specified average width.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. K. B. Cook, Secretary of Committee D-13 on Textile Materials, U. S. Rubber Co., 122 Adams St., Newark, N. J.

[2] 1924 Book of A.S.T.M. Standards.

Stitched Canvas Belting Ducks.

4. *Stitched Canvas Belting Ducks*, ranging in width from 16 to 72 in., inclusive:

(*a*) No individual measurement made to determine the width of the fabric shall be more than $\frac{1}{8}$ in. over or under the tolerance for the average width.

(*b*) The average width determined by measurement shall be as specified with the following tolerances:

Width, in.	Tolerance, in.	
	Over	Under
16 to 36, inclusive	$\frac{1}{4}$	$\frac{1}{4}$
37 to 60, inclusive	$\frac{3}{8}$	$\frac{1}{4}$
61 to 72, inclusive	$\frac{5}{8}$	$\frac{3}{8}$

II. WEIGHT

Normal Weight.

5. The weight of the fabric determined by test shall be not more than $2\frac{1}{2}$ per cent over or under the specified weight.

III. THREADS PER INCH

Hose Ducks.

6. *Hose Ducks.*—

(*a*) The average count of warp ends per inch determined by test shall be not more than 2 per cent over or under the specified count.

(*b*) The average count of filling picks per inch determined by test shall be not more than 4 per cent over or under the specified count.

Rubber Belt Ducks.

7. *Rubber Belt Ducks.*—

(*a*) The average count of warp ends per inch determined by test shall be not more than 2 per cent over or under the specified count.

(*b*) The average count of filling picks per inch determined by test shall be not more than 4 per cent over or under the specified count.

Stitched Canvas Belting Ducks.

8. *Stitched Canvas Belting Ducks.*—

(*a*) The average count of warp ends per inch determined by test shall be not more than 1 end over or under the specified count for fabrics counting not over 30 ends per inch and not more than $1\frac{1}{2}$ ends over or under for fabrics counting over 30 ends per inch.

(*b*) The average count of filling picks per inch determined by test shall be not more than 1 pick over or under the specified count for fabrics counting not over 15 picks per inch, and not more than $1\frac{1}{2}$ picks over or under for fabrics counting over 15 picks per inch.

IV. GAGE

Hose Ducks.

9. *Hose Ducks.*—The average thickness of the fabric shall be not more than 7 per cent over or under the specified average thickness.

10. *Rubber and Balata Belt Ducks.*—The average thickness of the fabric shall be not more than 5 per cent over or under the specified average thickness. **Rubber and Balata Ducks**

V. CRIMP

11. The average warp crimp shall not be more than 10 per cent over or under the specified crimp percentage, and the average filling crimp shall not be more than 20 per cent over or under the specified crimp percentage. **Crimp.**

VI. STRENGTH

12. The average tensile strength of the warp and the average tensile strength of the filling shall be not less than the average specified tensile strength. **Strength.**

TENTATIVE SPECIFICATIONS
FOR
TOLERANCES AND TEST METHODS FOR COTTON YARNS, SINGLE AND PLIED[1]

Serial Designation: D 180 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision

ISSUED, 1923; REVISED, 1924.

Scope. 1. These specifications cover the tolerances and methods of testing for cotton yarn, both single and plied.

TOLERANCES

I. STRENGTH

Strength of Yarn. 2. The average tensile strength of each case, bale, chain ball or beam warp of yarn, either single or plied, as found by test shall be not less than the specified strength.

II. SIZE OR YARN NUMBER

Size of Yarn, Carded and Combed. 3. The average size of each case, bale, chain ball or beam warp of yarn, in the singles, either carded or combed, as found by test shall not vary more than 3 per cent above or below the specified size.

Example.—No. 36 carded yarn specified; tolerance would allow 34.92 to 37.08.

III. TWIST AND DIRECTION OF TWIST

Definition. 4. *Direction of Twist.*—A yarn is said to contain right-hand twist when the spirals or twists run upward in a right-hand direction when the yarn is held in a vertical position, and conversely for left-hand twist.

Twist of Plied Yarns. 5. The average twist of each case, bale, chain ball or beam warp of plied yarns as found by test shall not vary more than 5 per cent above or below that specified.

Example.—Twist specified is 20 twists per inch; tolerance 19 to 21.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. K. B. Cook, Secretary of Committee D-13 on Textile Materials, U. S. Rubber Co., 122 Adams St., Newark, N. J.

METHODS OF TESTING

IV. STRENGTH

Two test methods are given, the skein test for single yarn and the single strand test for single and plied yarns. A Preferred and Alternative Method for each test is given. The Alternative Method can be used where routine testing is done on a large scale. The Preferred Method should always be used in case of dispute.

Strength Single Yarn—Skein Preferred.

6. *Skein Test* (*Preferred Method*).—A standard skein (120 yd.) shall be broken after conditioning of tubes or bobbins selected for test for 12 hours or of skeins for at least 3 hours in an atmosphere of 65 per cent relative humidity, 70° F. (21° C.). An automatic yarn power tester of inclination balance type, the maximum capacity of which shall be determined in accordance with a table of machine specifications, shall be used. The speed of the pulling jaw shall be 12 in. per minute. Any yarn reel having a $1\frac{1}{2}$-yd. perimeter may be used in preparing the skeins. For filling-wound yarns or yarns on cones, where the yarn is drawn from the top, a speed of 100 to 300 r.p.m. of reel shall be used. For warp-wound yarns or yarn on parallel tubes where the yarn is drawn from the side, a speed of 20 to 30 r.p.m. of reel shall be used. On reels that have only one pigtail guide, the tension shall be applied by making one full wrap of the yarn around the guide. On reels using two or more guides, the yarn shall pass straight through the guide onto the reel, the angles of the guides supplying the necessary tension. Judgment must be used in regard to the amount of tension required on yarns having little or a large amount of twist. Three tests from each of four bobbins from every case of yarn shall be made.

Strength, Single Yarn, Single Strand Preferred.

7. *Single Strand Test* (*Preferred Method*).—Single strands shall be broken after conditioning the tubes or bobbins for 12 hours in an atmosphere of 65 per cent relative humidity, 70° F. (21° C.). A single strand tester of proper capacity with the jaws set 10 in. between grips and having a speed of pulling jaw of 12 in. per minute shall be used. The average of 4 breaks from each of 10 bobbins shall be the average strength. This test shall be used for yarns received on beams, etc. To prepare specimens for test, at least 60 ends, 48 in. in length, shall be unwound from the beam. The bundle shall be held at one end to allow ends to twist upon themselves. A knot shall be tied in each end and the bundles allowed to condition as specified in Section 7. After conditioning, one end of the bundle shall be clamped in the head end jaw of any twist counter, and the other end shall be held by any suitable means, applying approximately the same tension as is used in preparing skeins on reels. The bundle shall be untwisted until strands are parallel, 60 ends counted off and cut

from the bundle to a measure of 1 yd. in length. Knots shall again be tied in each end and the size of the 60 yd. determined in accordance with Section 13. After the size has been determined the strands shall again be made parallel, removed one by one, and broken on a single strand tester. The average of 20 breaks shall be reported as the average strength.

Strength, Plied Yarns, Single Strand, Preferred.

8. *Plied Yarns (Preferred Method).*—Plied yarns, except standard tire cord, shall be subjected to the single strand break after conditioning for 12 hours on spools or tubes selected for test, in an atmosphere of 65 per cent relative humidity and 70° F. (21° C.). Standard tire cord shall be tested under dry conditions in accordance with the Standard Methods of Testing Cotton Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[1] A single strand tester of proper capacity with the jaws set 10 in. between grips and having a speed of pulling jaw of 12 in. per minute shall be used. The average of 4 breaks from each of 10 spools or tubes shall be reported as the average strength.

Strength for All Yarns, Alternative Method.

9. *Skein and Single Strand (Alternate Method).*—Skeins or single strands of yarn either single or plied, prepared in accordance with Sections 6, 7 and 8, shall be broken under natural humidity conditions at time of test. The results thus obtained shall be reduced to a common basis of standard moisture regain equal to 7 per cent of the bone-dry weight.

Moisture Regain Determination.

10. To determine moisture regain present in samples, the several skeins shall be weighed collectively, immediately after testing, under natural moisture conditions which obtain at the time of test. The skeins shall then be placed in the basket of an oven at a temperature of 105 to 110° C. (221 to 230° F.) and dried to constant weight. The moisture regain is then computed as the percentage of the dry weight.

Correction to Standard Regain.

11. (*a*) The following formula shall then be applied, based on the assumption that the standard moisture regain of cotton yarns is 7 per cent of the dry weight, that the actual percentage regain is between the limits of 3 and 7 per cent of the dry weight and that for 1 per cent of moisture regain there is an increase of 6 per cent in the tensile strength of the yarn.

$$\begin{array}{c}\text{Tensile strength corrected}\\ \text{to standard moisture regain}\end{array} = \frac{(\text{Tensile strength from machine reading}) \times 142}{100 + (6 \times \text{actual percentage regain.})}$$

Example.—With a skein of yarn broken under natural conditions showing a tensile strength of 120 lb. as read from the machine dial, and which by weighing before and after drying the skein was found to contain a moisture regain equal to 5 per cent of the bone-dry weight, the tensile strength corrected to a common basis of 7 per cent moisture regain would be:

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[1] 1924 Book of A.S.T.M. Standards.

$$\text{Corrected tensile strength} = \frac{120 \times 142}{100 + (6 \times 5)} = 131 \text{ lb.}$$

(*b*) Moisture regain tests shall be made periodically during the hours of testing as the natural humidity conditions are found to vary.

Strength Correction to Size.

12. The average tensile strength shall be corrected to the specified size as determined in accordance with Sections 13, 14 and 15, by the following formula:

$$\text{Corrected tensile strength} = \text{Actual average strength} \times \frac{\text{Actual average size}}{\text{Specified size}}$$

V. SIZE OR YARN NUMBER

Size of Single Yarns, Preferred Method.

13. The size of all standard skeins used in the skein strength test described in Section 6 shall be determined immediately after being broken. In case the single strand test is made, the standard skein shall be prepared for the size determination at the time of the break and the size determined immediately. The size of 60-yd. bundles prepared from beams as described in Section 7 shall be determined as soon as possible after conditioning and one test from each beam shall be reported as the average size. The balance to be used in this test shall be accurate to 0.25 per cent of the standard size of the yarn. When the balance does not indicate the size directly, the yarn number or size may be calculated from the formula:

$$\text{Yarn number or size} = \frac{\text{Length in yards of single yarn}}{\text{Weight in grains}} \times \frac{7000 \text{ (grains in 1 lb.)}}{840 \text{ (yards of No. 1 cotton yarn per pound)}}$$

Size of Plied Yarns, Preferred Method.

14. In determining the size of plied yarns, the skein shall be prepared in accordance with Table I, and the size shall be determined after conditioning of tubes or spools selected for test for 12 hours or of skeins for at least 3 hours, in an atmosphere of 65 per cent relative humidity, and 70° F. (21° C.). Any yarn reel having a $1\frac{1}{2}$-yd. perimeter may be used in preparing the skeins. For filling-wound yarns or yarn on cones, a speed of 100 to 300 r.p.m. of reel shall be used. For warp-wound yarns or yarn on parallel tubes, a speed of 20 to 30 r.p.m. of reel shall be used. On reels that have only one pigtail guide, the tension shall be applied by making one full wrap of the yarn around the guide. On reels using two or more guides, the yarn shall pass straight through the guides onto the reel, the angles of the guides supplying the necessary tension.

TABLE I.

EQUIVALENT SINGLES SIZE	YARDS FOR SIZE	CONVERSION FORMULA	NUMBER OF TESTS PER CASE OF YARN
20's and above	60	$\frac{\text{Size}}{2} = \text{Ply size}$	3 from each of 4 spools or tubes
3's to 20's	24	$\frac{\text{Size}}{5} = \text{Ply size}$	3 from each of 4 spools or tubes
Below 3's	12	$\frac{\text{Size}}{10} = \text{Ply size}$	3 from each of 4 spools or tubes

Size of All Yarns, Alternate Method.

15. All yarns used in the alternative method of testing for strength (Section 9) shall be sized under natural humidity conditions at the time of test. Plied yarns shall be prepared in skeins in accordance with Table I. The moisture regain shall then be determined as specified in Section 10, and results corrected to a common basis of standard moisture regain equal to 7 per cent of the bone-dry weight by means of the formula:

$$\text{Size corrected to standard moisture regain} = \frac{\text{Size} \times (100 + \text{actual percentage regain})}{107}$$

The average of these tests shall be the average size of case, bale, ball chain or beam warp of yarn.

VI. TWIST

Twist of Single Yarns.

16. No precision method for determining the twist of single yarns has been developed.

Twist of Plied Yarns.

17. The ply twist in yarns of 2 or more ply shall be determined on any standard twist counter with jaws set 10 in. apart. The strands shall be clamped in jaws under a definite tension by attaching weights. The tension to be used shall be determined from the formula:

$$\text{Tension, in grams} = \frac{156 \text{ (Constant)}}{\text{Equivalent singles size}}$$

Example.—The weight for 23/11 would be as follows:

$$\frac{156}{2.09} = 76 \text{ g.}$$

The constant of 156 represents a tension which should be placed on yarn or cord to hold it sufficiently taut and still not remove any stretch.

Number of Tests.

18. Three twist tests on each of 4 packages of yarn from each case shall be made, and the average of these 12 tests shall be the average of the case.

TENTATIVE SPECIFICATIONS
FOR
TOLERANCES AND TEST METHODS FOR ELECTRICAL COTTON YARNS[1]

Serial Designation: D 203 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

Scope.

1. These specifications cover the tolerances and methods of testing for electrical cotton yarns, both single and multiple wound.

TOLERANCES

I. STRENGTH

Strength of Yarn.

2. The average tensile strength of each case or bale of yarn, either single of plied, as found by test shall be not less than the specified strength.

II. SIZE OR YARN NUMBER

Size of Yarn, Carded and Combed.

3. The average size of each case or bale of yarn, in the singles, either carded or combed, as found by test shall not vary more than 3 per cent above or below the specified size.

Example.—No. 36 carded yarn specified; tolerance would allow 34.92 to 37.08.

III. TWIST AND DIRECTION OF TWIST

Definition.

4. *Direction of Twist.*—A yarn is said to contain right-hand twist when the spirals or twists run upward in a right-hand direction, when the yarn is held in a vertical position, and conversely for left-hand twist.

Twist of Plied Yarns.

5. The average twist of each case or bale of plied yarn as found by test shall not vary more than 5 per cent above or below that specified.

Example.—Twist specified is 20 twists per inch; tolerance 19 to 21.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. K. B. Cook, Secretary of Committee D-13 on Textile Materials, U. S. Rubber Co., 122 Adams St., Newark, N. J.

METHODS OF TESTING

IV. STRENGTH

Testing Machine. 6. All skeins shall be broken on an automatic power yarn tester of inclination balance type of 150 and 300-lb. capacities. The lower capacity should be used until the swing of the pendulum exceeds an angle of 45 deg. from the vertical. When yarns break above this mark, the higher capacity of testing machine should be used.

Spools. 7. The spools used in holding skeins during testing shall not be less than 1 in. in diameter, and not less than 1 in. in width. The upper or head end spool should be fastened solidly, and the lower spool be allowed to revolve.

Speed of Separation. 8. The speed of pulling jaw shall be 12 in. per minute.

Reels. 9. Any yarn reel having a $1\frac{1}{2}$-yd. perimeter may be used in preparing the skeins. For yarn wound on cones, where the yarn is drawn from the top, a speed of 100 to 300 r.p.m. of reel shall be used. For yarn wound on parallel tubes, the yarn shall be drawn from the side, and a speed of 20 to 30 r.p.m. of reel shall be used. On reels that have only one pigtail guide and for yarns on cops or cones, either single end or multiple wound, the tension shall be applied by making one full wrap around the guide. For yarns on parallel tubes, either single end or multiple wound, there shall be no wraps around the guide. On reels using two or more guides, the yarn, either single end or multiple wound, shall pass straight through the guides onto the reel, the angles of the guides supplying the necessary tension. Judgment must be used in regard to the amount of tension required on yarns having little or a large amount of twist.

Number of Tests. 10. Three tests from each of four cops, cones or tubes of yarn from every case shall be made, and the average of these twelve tests shall be the average of the case.

Two skein test methods are given, *A*, Preferred Method and *B*, Alternate Method. The Alternate Method can be used where routine testing is done on a large scale. The Preferred Method should always be used in case of dispute.

A. Preferred Method

Strength, Single End Yarn. 11. For single end yarn a standard skein (120 yd.) shall be broken after conditioning in an atmosphere of 65 per cent relative humidity, and 70° F. (21° C.).

Strength, Multiple Wound Yarns. 12. For multiple wound yarn, a skein shall be prepared in accordance with Table I, and shall be broken after conditioning in an atmosphere of 65 per cent relative humidity, and 70° F. (21° C.). The table provides for skeins of approximately 120 yd. of single yarn or

80 loops. No skeins shall be less than 10 loops or 15 yd. of multiple strand.

TABLE I.

NUMBER OF ENDS IN SINGLE STRAND	LENGTH TO REEL FOR TEST, YD.
2	60
3	45
4 and 5	30
6 and 7	21
8 and above	15

Conditioning.

13. Cops, cones and tubes selected for test shall be conditioned for at least 12 hours. Yarn removed for testing after conditioning shall not penetrate into a tube a distance of more than $\frac{1}{4}$ in. on a radial line. Skeins shall be conditioned for at least 3 hours.

B. Alternate Method

Strength, Single.

14. Skeins of either single end or multiple wound yarn prepared as outlined in Method *A* shall be broken under natural humidity conditions at the time of test. The results thus obtained shall be reduced to a common basis of standard moisture regain equal to 7 per cent of the bone-dry weight.

Moisture Regain Determination.

15. To determine moisture regain present in samples, the several skeins shall be weighed collectively, immediately after testing, under natural moisture conditions which obtain at the time of test. The skeins shall then be placed in the basket of an oven at a temperature of 105 to 110° C. (221 to 230° F.) and dried to constant weight. The moisture regain is then computed as the percentage of the dry weight.

Correction to Standard Regain.

16. The following formula shall then be applied, based on the assumption that the standard moisture regain of cotton yarns is 7 per cent of the dry weight, that the actual percentage regain is between the limits of 3 and 7 per cent of the dry weight, and that for 1 per cent of moisture regain there is an increase of 6 per cent in the tensile strength of the yarn:

$$\begin{array}{c}\text{Tensile strength corrected to}\\ \text{standard moisture regain}\end{array} = \frac{(\text{Tensile strength from machine reading}) \times 142}{100 + (6 \times \text{actual percentage regain})}$$

Example.—With a skein of yarn broken under natural conditions showing a tensile strength of 120 lb. as read from the machine dial and which by weighing before and after drying the skein was found to contain a moisture regain equal to 5 per cent of the bone-dry weight, the tensile strength corrected to a common basis of 7 per cent moisture regain would be:

$$\text{Corrected tensile strength} = \frac{120 \times 142}{100 + (6 \times 5)} = 131 \text{ lb.}$$

(*b*) Moisture regain tests shall be made periodically during the hours of testing as the natural humidity conditions are found to vary.

C. *Strength Correction to Size*

Strength Correction to Size.

17. The average tensile strength shall be corrected to the specified size as determined in accordance with Sections 18 and 19 by the following formula:

$$\text{Corrected tensile strength} = \text{Actual average strength} \times \frac{\text{Actual average size}}{\text{Specified size}}$$

V. SIZE OR YARN NUMBER

Yarn Number, Preferred Method.

18. All skeins used in the Preferred Method of testing for strength shall be sized immediately after being broken.

Yarn Number, Alternate Method.

19. All skeins used in the Alternate Method of testing for strength shall be sized under natural humidity conditions at the time of test. The moisture regain shall then be determined as outlined in Section 15 and the results corrected to a common basis of standard moisture regain equal to 7 per cent of the bone-dry weight by means of the following formula:

$$\begin{array}{c}\text{Size corrected to standard}\\ \text{moisture regain}\end{array} = \frac{\text{Size} \times (100 + \text{actual percentage of regain})}{107}$$

Balance.

20. The balance to be used shall be accurate to 0.25 per cent of the standard size of the yarn. When the balance does not indicate the size directly, the yarn number or size may be calculated from the formula:

$$\text{Yarn number or size} = \frac{\begin{array}{c}\text{Length in yards of}\\ \text{single yarn}\end{array}}{\text{Weight in grains}} \times \frac{7000 \text{ (grains in 1 lb.)}}{\begin{array}{c}840 \text{ (yards of No. 1 cot-}\\ \text{ton yarn per pound)}\end{array}}$$

Number of Tests.

21. The average size of the 12 skeins used in the strength test shall be the average size of case or bale.

VI. TWIST

Twist of Plied Yarns.

22. The ply twist in yarns of 2 or more ply shall be determined on any standard twist counter with jaws set 10 in. apart. The strands shall be clamped in jaws under a definite tension by attaching weights. The tension to be used shall be determined from the formula:

$$\text{Tension, in grams} = \frac{156 \text{ (Constant)}}{\text{Equivalent singles size}}$$

Example.—The weight for 80/2 ply would be as follows.

$$\frac{156}{40} = 3.9 \text{ g. (approximately)}$$

The constant of 156 represents a tension which should be placed on yarn or cord to hold it sufficiently taut and still not remove any stretch.

Number of Tests.

23. Three twist tests on each of 4 packages of yarn from each case shall be made, and the average of these 12 tests shall be the average of the case.

TENTATIVE SPECIFICATIONS
FOR
TOLERANCES AND TEST METHODS FOR COTTON SEWING THREADS[1]

Serial Designation: D 204 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

TOLERANCES

I. STRENGTH

Strength. 1. The average tensile strength of each case of sewing thread as found by test shall be not less than the specified strength.

II. YARDAGE

Yards per Pound. 2. When thread is sold by weight instead of on a guaranteed yardage unit, the yards per pound shall be indicated on each tube, spool or cone.

Variation. 3. The actual number of yards per pound or unit of sale, as found by test, shall not be more than 4 per cent less than the number of yards per pound or unit of sale specified.

III. TWIST

Definition. 4. *Direction of Twist.*—A sewing thread is said to contain right-hand twist when the spirals or twists run upward in a right-hand direction, when the thread is held in a horizontal position, and conversely for left-hand twist.

Balance. 5. The finished sewing thread shall be balanced in twist as nearly as possible and in no case shall a yard of thread when drawn from the side of a spool or package twist upon itself more than six times when brought together to form a loop.

IV. RUNNING QUALITIES

Running. 6. In addition to meeting the foregoing requirements, sewing thread shall be subjected to a sewing machine test under actual factory conditions and in the event that any thread causes more than a reasonable number of stoppages it shall be subject to rejection.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. K. B. Cook, Secretary of Committee D-13 on Textile Materials, U. S. Rubber Co., 122 Adams St., Newark, N. J.

METHODS OF TESTING

V. STRENGTH

Strength. 7. All threads shall be tested by the single strand test method. A single strand tester of proper capacity with jaws set 10 in. between grips and having a speed of pulling jaw of 12 in. per minute shall be used. The average of four breaks from each of ten spools or packages shall be the average strength. Any tests during which the thread breaks at the jaw due to pinching or cutting shall not be included in the average.

VI. YARDAGE

Yards per Pound. 8. In determining the yards per pound of sewing thread, the skeins shall be prepared in accordance with Table I. Any yarn reel having a $1\frac{1}{2}$-yd. perimeter may be used in preparing the skeins. On reels that have only one pigtail guide, tension shall be applied by making one full wrap of the thread around the guide. On reels using two or more guides, the thread shall pass straight through the guide onto the reel, the angles of the guides supplying the necessary tension.

TABLE I.

EQUIVALENT SINGLE SIZE	YARDS FOR TEST	NUMBER OF TESTS PER CASE OF THREAD
Finer than 10's	120	3 from each of 4 spools
10's and coarser	60	3 from each of 4 spools

The skeins shall then be weighed and the average weight of the 12 skeins shall be converted to yards per pound from the formula:

$$\text{Yards per lb.} = \frac{7000 \times (\text{number of yards in skein})}{\text{Average weight in grains of skein}}$$

VII. TWIST AND BALANCE

Twist in Singles. 9. No precision method for determining the twist of single yarns has been developed.

Twist in Ply. 10. Ply twist shall be determined on any standard twist counter with the jaws set 10 in. apart. The strands shall be clamped in jaws under a definite tension obtained by attaching weights. The tension to be used shall be determined from the formula:

$$\text{Tension, in grams} = \frac{156\ (\text{Constant})}{\text{Equivalent singles size}}.$$

Example.—The weight for 24/4 would be as follows:

$$\frac{156}{6} = 26\text{ g.}$$

The constant of 156 represents a tension which should be placed on yarn or thread to hold it sufficiently taut and still not remove any stretch.

Balance. 11. The "balance" of a sewing thread shall be determined by removing one yard of thread from a spool or package, holding it at each end and bringing these ends together, allowing the thread a chance to loop.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
OSNABURG CEMENT SACKS[1]

Serial Designation: D 205 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision

Issued, 1924

1. All test procedure not covered in these specifications shall be in accordance with the Standard Methods of Testing Cotton Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[2] **Standard Methods.**

2. Tolerances shall be the limit within which the fabric or sacks must come in their specified characteristics in order that they shall constitute a good delivery on contract. **Tolerances.**

I. SAMPLING

3. Ten bales shall be taken at random from each carload of sacks and one sack shall be taken for test purposes from each of these bales. Test sacks shall be selected and tested promptly after receipt of shipment. **Sampling.**

II. REQUIREMENTS AND METHODS OF TEST

A. Material (Osnaburg)

4. The width when measured at right angles to the selvage with the material smoothed out flat with only sufficient tension to remove wrinkles shall be not less than 29½ in. nor more than 31 in., the desired width being 30 in. **Width.**

5. The desired weight of the material being 7 oz. per lineal yard (8.4 oz. per sq. yd.), the average bale weight of 500 sacks shall be not more than 3 per cent under the 7 oz.-per-lineal-yard requirement. **Weight.**

6. The desired thread count is 38 or more per inch in the warp and 28 or more per inch in the filling. A tolerance of 1 thread under in either warp or filling will be permitted. **Thread Count.**

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. K. B. Cook, Secretary of Committee D-13 on Textile Materials, U. S. Rubber Co., 122 Adams St., Newark, N. J.

[2] 1924 Book of A.S.T.M. Standards.

Tensile Strength. 7. (*a*) The tensile strength in both the warp and filling shall be 75 lb. with a tolerance of not more than 5 lb. under the desired tensile strength.

(*b*) The tensile strength shall be determined under prevailing atmospheric conditions except in the settlement of disputes, in which case the test for tensile strength shall be made upon material having a normal moisture content obtained by exposure for at least 4 hours to an atmospheric condition of 65-per-cent-relative humidity at a temperature of 21° C. (70° F.).

Sizing. 8. No sizing or loading compound that is known to be injurious to the material or that will materially affect its weight or strength shall be used.

B. Sacks

Cut. 9. (*a*) The cut of the sacks shall average that specified by the purchaser and shall be measured with the seams ripped out and with the material folded down the center parallel to the selvage, the measurement to be made along the fold of the material which shall be held with only sufficient tension to smooth out the wrinkles. No individual sack shall measure more than $\frac{3}{8}$ in. less than the size specified, for the shipment to be accepted as good delivery.

(*b*) If the cut averages less than, but within $\frac{1}{2}$ in. of that specified, the shortage shall be subject to adjustment between the seller and purchaser.

(*c*) If the cut averages more than $\frac{1}{2}$ in. less than that specified, the sacks may be rejected.

Seams. 10. The seams shall be $\frac{1}{2}$ in., sewed with a two-thread stitch with not less than 7 stitches to 2 in. The thread shall be of No. 10 yarn of three and five-ply or their equivalent in strength of other ply and number.

Hem. 11. The hem shall be as specified by the purchaser.

Printing. 12. The printing on the sack shall be as specified by the purchaser.

Valve Size. 13. The size of the valve of the sack shall be as specified by the purchaser.

III. REJECTION AND RETESTING

Retest. 14. (*a*) Should the test sacks fail to conform to the requirements specified, a retest shall be made before final rejection of the shipment.

(*b*) Sacks for retest shall be taken from ten other bales taken at random as specified in Section 3.

Rejection. 15. If the sacks tested in the retest fail to conform to the requirements specified, the entire shipment may be rejected.

TENTATIVE METHODS OF TENSION TESTING OF METALLIC MATERIALS[1]

Serial Designation: E 8 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

Issued, 1924

These methods deal with the form and dimensions, the machining, and the testing of tension test specimens of metallic materials. Such matters as methods of taking samples from which to prepare test specimens are treated in the individual specifications for ferrous metals and for non-ferrous metals.

I. TEST SPECIMENS

1. In recommending the following specimens for use in tension tests it is not intended to exclude entirely the use of other test specimens for special materials or for special forms of material; for example, in tests of tubing and pipe the form of specimen recommended for plate, shape and flat material (Fig. 1) is not generally suitable for use, and a special form of specimen is specified. It is, however, recommended that wherever it is feasible the specimens here recommended be used.

Wire, Rods and Pipe.

2. Tension test specimens of wire are of the full-size diameter as drawn, and tension test specimens of rods of ductile metal are often of the full-size diameter as rolled. Tension test specimens of pipe and of tubing are frequently of full size as manufactured, in which case the ends should be plugged with metal plugs which do not extend within the gage marks.

Plates, Shapes and Flats.

3. The tension test specimen shown in Fig. 1 is recommended for plate, shape and flat material. The thickness of the specimen is that of the material tested.

Note.—When it is desired to use a specimen with a gage length of less than 8 in., the general proportions of Fig. 1 should be followed. Specimens with a gage length of 2 in. are occasionally used. When it is not convenient to machine specimens to the standard shape shown in Fig. 1, specimens may be used with edges machined parallel for the entire length of the specimen. If such specimens are, machined with a tool cutting across the edges of the specimen it is important that the transverse tool marks be removed before the specimen is tested.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. F. Moore, Chairman of Sub-Committee, of Committee E-1, on Mechanical Testing of Metallic Materials, University of Illinois, Urbana, Ill.

These methods are in effect a revision of the Methods for Tension Tests of the Standard Methods of Mechanical Testing of Metallic Materials. The standard methods, which were last published under the Serial Designation: E 1 – 18, have accordingly been withdrawn.

For thick plate material, it is usually preferable to use a machined specimen rather than to use a specimen the full thickness of the plate.

Up to the present time it has not been possible to fix a definite line between plate material and sheet material.

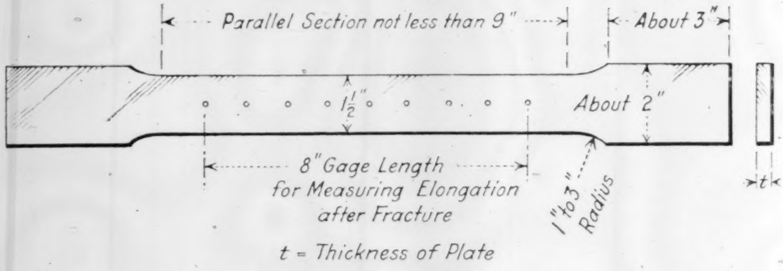

Parallel Section not less than 9"
About 3"
$1\frac{1}{2}$"
About 2"
8" Gage Length for Measuring Elongation after Fracture
1" to 3" Radius
t
t = Thickness of Plate

FIG. 1

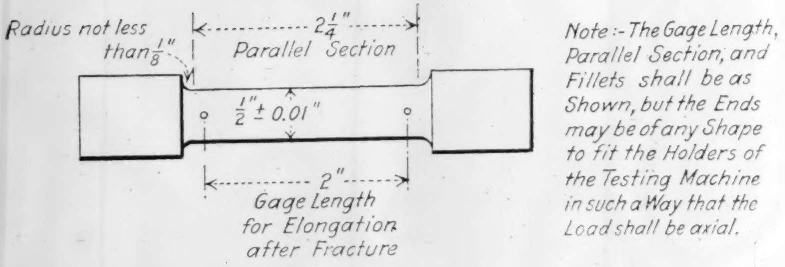
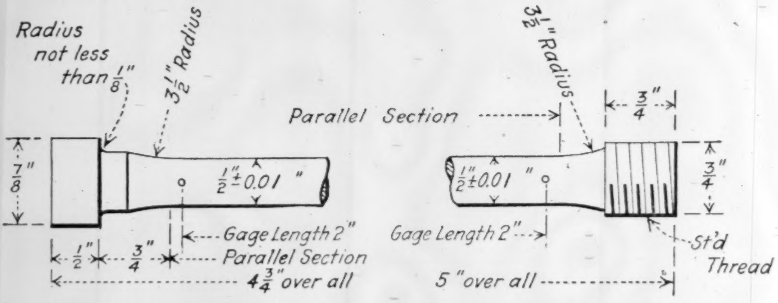

Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2


Radius not less than $\frac{1}{8}$"
$3\frac{1}{2}$" Radius
$\frac{7}{8}$"
$\frac{1}{2}$" ± 0.01 "
Gage Length 2"
Parallel Section
$\frac{1}{2}$"
$\frac{3}{4}$"
$4\frac{3}{4}$" over all
$3\frac{1}{2}$" Radius
Parallel Section
$\frac{3}{4}$"
$\frac{1}{2}$" ± 0.01 "
$\frac{3}{4}$"
Gage Length 2"
St'd Thread
5 " over all

(*a*) Specimen with shouldered ends. (*b*) Specimen with threaded ends.

FIG. 3

4. The tension test specimen shown in Fig. 2 is recommended for general use in testing metals.[1] The gage length for measuring elongation after fracture is 2 in.

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[1] It was suggested in discussion that attention be called to Section 7.—ED.

5. When it is necessary to cut specimens from material (other than plate, shape and flat material) which is of such size that the specimen shown in Fig. 2 cannot be used, it is recommended that a specimen with dimensions proportional to those shown in Fig. 2 be used and that the specimen be made as large as feasible. In any such small-size specimen it is especially important that the gage length for measuring elongation be four times the diameter of the specimen.

Measurement of Cross-Section.

6. In all tension tests of metals the actual dimensions of cross-section of the test specimens shall be measured with a micrometer reading to $\frac{1}{200}$ of the dimension measured, and the stresses shall be computed on the basis of the measured cross-section; it should never be assumed that the dimensions of the measured cross-section are identical with the nominal dimensions.

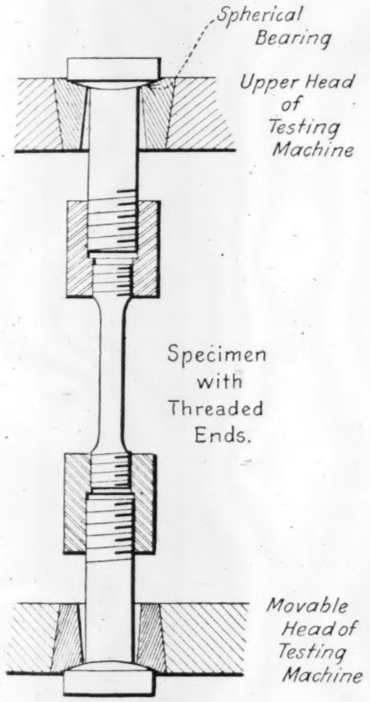
Spherical Bearing
Upper Head of Testing Machine
Specimen with Threaded Ends.
Movable Head of Testing Machine

FIG. 4

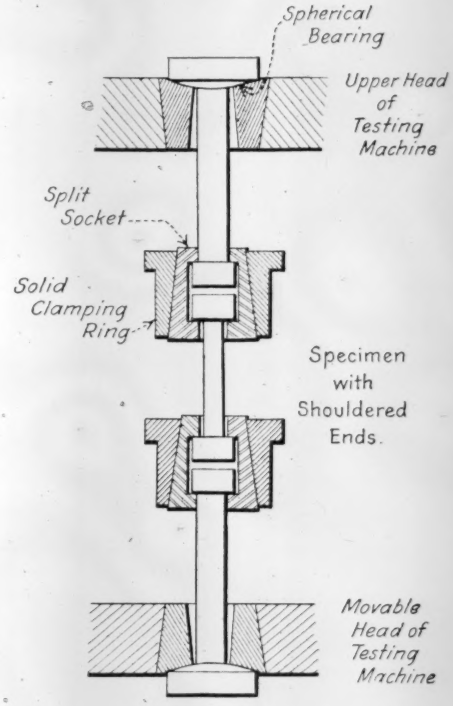
Spherical Bearing
Upper Head of Testing Machine
Split Socket
Solid Clamping Ring
Specimen with Shouldered Ends.
Movable Head of Testing Machine

FIG. 5

NOTE.—It will be noted that the tolerance for diameter of specimens shown in Fig. 2 permits the use of specimens 0.505 in. in diameter.

Ends.

7. The shape of the ends of the specimen shown in Fig. 2 are not specified above. For specimens of brittle metal it is desirable

that the diameter of the specimen be changed gradually along its length from the minimum section at the gage length to the diameter at the ends. Fig. 3 shows two forms of end of specimen which have given satisfactory results in tests of brittle metals.

Finish. 8. Specimens shall be finished so that the surfaces are smooth and free from nicks and tool marks. All ragged edges shall be smoothed.

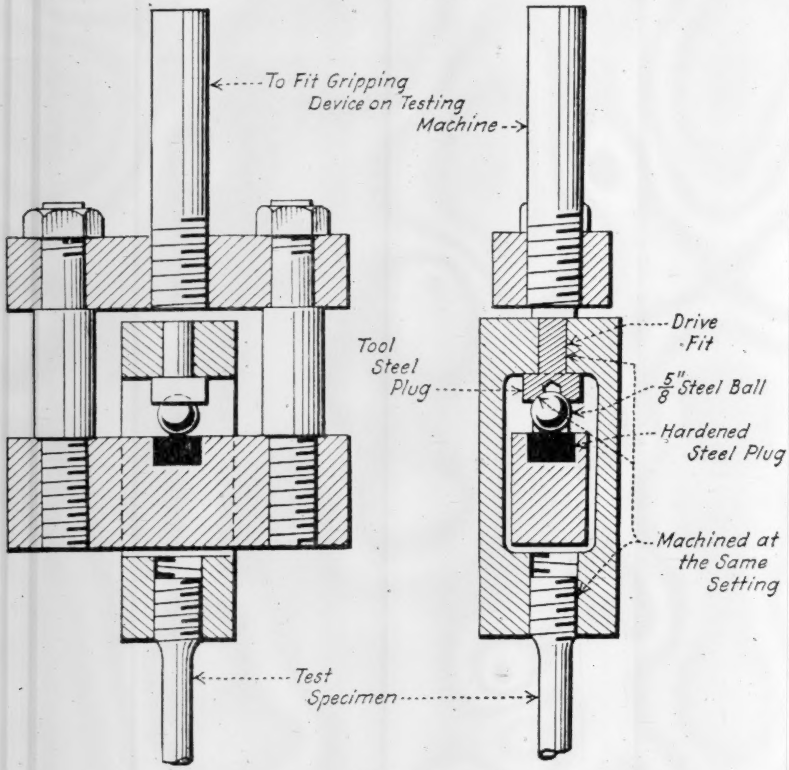
To Fit Gripping Device on Testing Machine
Tool Steel Plug
Drive Fit
5/8" Steel Ball
Hardened Steel Plug
Machined at the Same Setting
Test Specimen

FIG. 6

The gripping device is shown as used with threaded end specimens. A similar device fitted with split sockets would be used with shouldered specimens.

II. GRIPPING DEVICES FOR TENSION TEST SPECIMENS

Wedge Grips. 9. For long bars of ductile metal and for the flat plate test specimen shown in Fig. 1, wedge grips, bearing directly on the end of the test specimen, generally furnish a satisfactory means of gripping the specimens.

Grips for Brittle Material. 10. For short specimens and for specimens of brittle material, wedge grips are not a satisfactory means of holding test specimens; it is necessary to use machined specimens and to use special means for insuring that the specimen, when under load, shall be as nearly as possible in pure axial tension. Fig. 4 shows a device for gripping tension specimens with threaded ends and Fig. 5 shows a device for gripping specimens with shouldered ends. Both these gripping devices are attached to the heads of the testing machine through

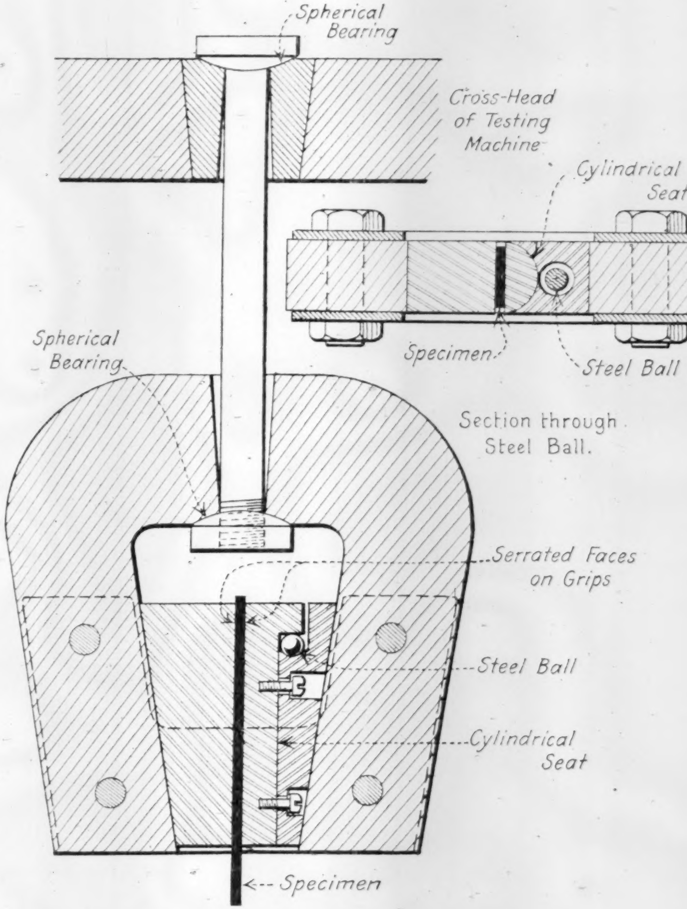
Spherical Bearing
Cross-Head of Testing Machine
Cylindrical Seat
Spherical Bearing
Specimen
Steel Ball
Section through Steel Ball.
Serrated Faces on Grips
Steel Ball
Cylindrical Seat
Specimen

FIG. 7

spherical-seated bearings. The distance between spherical bearings should be as great as is feasible. For brittle materials, even the spherical-seated bearings shown in Figs. 4 and 5 are not always effective in avoiding bending stress on the specimen. The gripping device shown in Fig. 6 has proved satisfactory for testing such specimens, and is an excellent gripping device for any machined tension test specimen.

Grips for Sheet Material. 11. For specimens cut from thin plate material and from sheet material, ordinary wedge grips are liable to cut the specimens near the edges, giving a tearing stress rather than an axial tension. The self-adjusting grips shown in Fig. 7 have proved satisfactory for tests of thin sheet copper and aluminum.

Grips for Wire. 12. For tests of specimens of wire, ordinary wedge grips are liable to cut the wire at the edges of the grips. This cutting has been found to be largely eliminated by the use of grips of the form shown in Fig. 8.

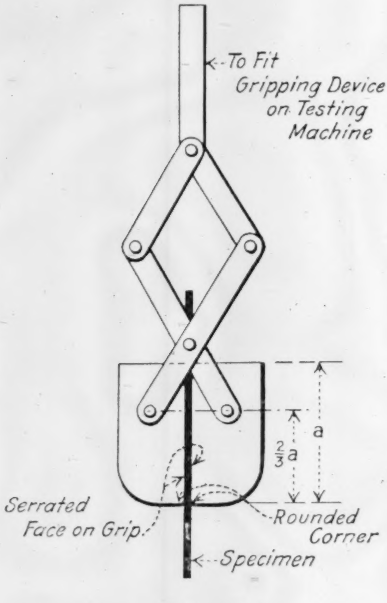

FIG. 8

Alignment. 13. In making tension tests, care shall be taken to see that the axis of the test specimen is located in the center line of the heads of the testing machine and that the liners used behind wedge grips are of proper thickness. From time to time the openings in the heads of the testing machine shall be lined up and the heads tested for parallelism. Deviations from correct alignment and from parallelism should not exceed 0.01 in.[1] The movable head of the machine should be free from sidewise motion that is visible to the unaided eye as the machine is run at its fastest speed.

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[1] It was pointed out in discussion that a phrase might be added to the effect that this deviation should be the limiting one throughout the range of movement during testing. See discussion of the Report of Committee E-1, p. 729.—ED.

III. SPEED OF OPERATION OF TESTING MACHINE

14. The pulling speed has a marked influence on the tensile properties shown by materials tested, an increase in speed increasing the values found for yield point and tensile strength. In testing specimens of metallic materials in gage lengths of 2 and 8 in., the speed of the machine, by which is meant the speed of the cross-head when the machine is running idle, shall conform to the following requirements:

The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the values given in the following table be exceeded, which values represent the extreme of good laboratory practice for steel:[1]

Specified Minimum Tensile Strength of Material, lb. per sq. in.	Gage Length, in.	Maximum Cross-head Speed, in. per minute	
		Yield Point	Tensile Strength
80 000 or under	2	0.50	2.0
	8	2.00	6.0
Over 80 000	2	0.25	1.0
	8	0.50	2.0

15. In determining the elastic limit in accordance with Method I, Section 17, the cross-head speed for the 2-in. gage length shall not exceed 0.125 in. per minute.

16. In determining the elastic limit by Method II, Section 17, the cross-head speed shall not exceed 0.025 in. per inch of gage length per minute.

IV. THE DETERMINATION OF ELASTIC LIMIT, YIELD POINT, AND TENSILE STRENGTH

Elastic Limit.

17. The term "elastic limit" is defined as follows:

Elastic Limit.—The greatest stress which a material is capable of withstanding without a permanent deformation remaining upon complete release of the stress.

The determination of the elastic limit as thus defined would logically involve the application and release of a succession of increasing loads on a test specimen until there was observed deformation after release of a load. This procedure is very slow and since experience does not indicate any appreciable difference between the elastic limit and the limit of proportionality of stress to strain (sometimes called the proportional limit), the determination of the stress at the limit of proportionality of stress to strain is regarded as an accurate determination of the elastic limit.

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[1] It was pointed out in discussion that it might well be emphasized that these speeds are too high for non-ferrous metals. See discussion of the Report of Committee E-1, p. 731.—ED.

It is obvious that the values obtained in tests for determining the elastic limit will depend on the delicacy of methods and instruments used. It becomes necessary, therefore, that in any test the method used in obtaining the elastic limit be clearly stated. The following methods are in common use for determining a value designated as the elastic limit.

Method I, proposed by Committee A-1 on Steel, and embodied in a number of specifications for steel. (For tension tests only.) The elastic limit shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer may then be removed from the specimen and the test continued to determine the tensile strength.

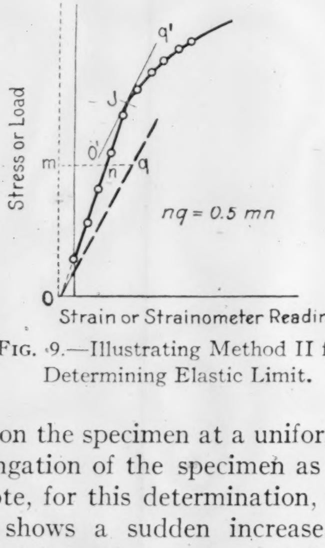

FIG. 9.—Illustrating Method II for Determining Elastic Limit.

Method II (proposed by the late J. B. Johnson) is a somewhat more delicate method for locating the elastic limit than is Method I. In Method II, the elastic limit shall be taken as that stress at which the rate of deformation is 50 per cent greater than the initial rate of deformation. A stress-strain diagram is necessary for determining the elastic limit by this method. It is illustrated in Fig. 9. The initial rate of deformation is given by the ratio $mn:Om$. $nq = 0.5\ mn$, $mq = 1.5\ mn$, and the slope of Oq represents a rate of deformation

50 per cent greater than the initial rate. $O'q'$ is drawn parallel to Oq and tangent to the stress-strain diagram. The point of tangency J locates the elastic limit. In using Method II the same precautions should be observed in attaching the strainometer as for the determination of the elastic limit by Method I. Method II, in tension tests of metals, gives lower values for the elastic limit than does Method I. It is recommended that in using Method II for tension tests the strainometer be of such sensitiveness that it will indicate a change of strain of 0.0001 in. per inch of gage length (0.0001 mm. per millimeter of gage length).

Methods of High Precision.—When it is desired to determine the elastic limit with a high degree of precision, it is suggested that the experimenter devise his own procedure, and in reporting his results describe the procedure in detail, including a statement of the limits of sensitiveness of the apparatus used and of the procedure used in plotting the stress-strain diagram from which the determination of elastic limit is made. It is to be remembered that the accurate determination of the elastic limit requires the use of accurate and sensitive instruments and the use of accurate methods of plotting test data.

Yield Point.

18. The term "yield point" is defined as follows:

Yield Point.—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

Two methods are in use for determining the yield point: (I) The "drop of the beam" method, and (II) the method by use of dividers:

Method I.—In Method I, load is applied to the specimen at a steady rate of increase and the operator keeps the beam in balance by running out the poise at a steady rate. At the yield point the increase of load stops (and for some metals there is an actual falling off of load), but the operator, running out the poise at a steady rate, runs it a trifle beyond the balance position, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device there is a sudden halt of the load-indicating pointer, corresponding to the drop of the beam. The load at the "halt" or the "drop" is recorded, and the corresponding stress is taken as the yield point. This method of determining the yield point requires only one man to conduct the test.

Method II.—In Method II for determining the yield point, one observer keeps the beam of the testing machine balanced, and another observer with a pair of dividers watches for visible elongation between two gage marks on the specimen. When visible stretch is observed the fact is at once reported to the man operating the beam of the testing machine, the load at that instant is noted, and the stress corresponding to the load is taken as the yield point. When a strainometer[1] is used in place of dividers a deformation of 0.01 in. over a gage length of 2 in. shall be regarded as indicating the yield point.

Some metals do not have a well-defined yield point.

Tensile Strength.

19. The term "tensile strength" is defined as follows:

Tensile Strength.—The maximum tensile stress which a material is capable of withstanding.

NOTE.—In practice, it is considered to be the maximum stress carried by a specimen representing the material in a tension test to rupture, under definite prescribed conditions.

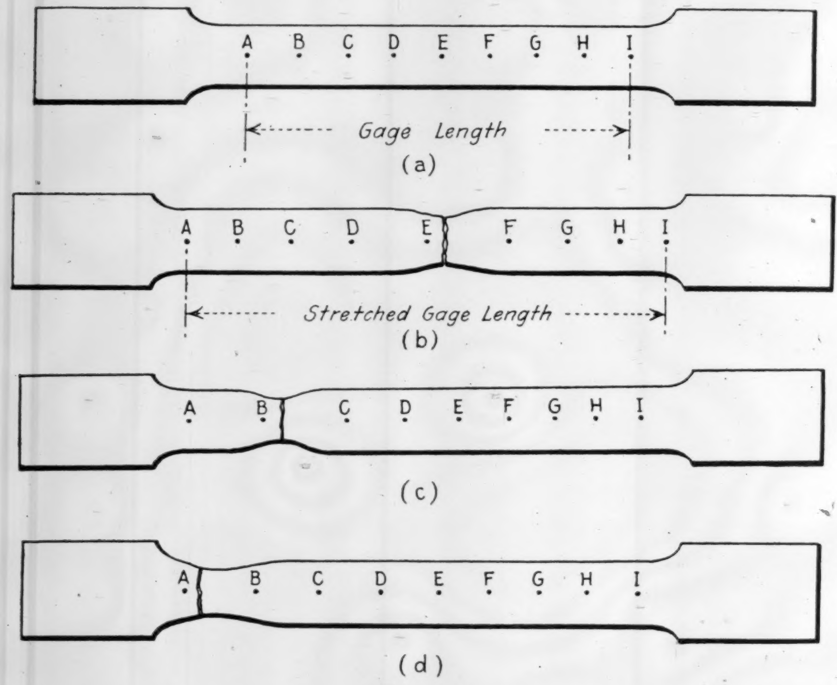

FIG. 10.

The conditions that must be prescribed in a tension test of metallic materials are the form of specimen, the method of gripping the specimen, and the rate of application of load. These are covered in foregoing sections. No further detailed discussion of methods of determining tensile strength is necessary, as there is involved merely the observing and the recording of the maximum load carried by the specimen during the test.

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[1] The determination of yield point with a strainometer is sometimes made in tests on non-ferrous metals. See discussion of the Report of Committee E-1, p. 728.—ED.

V. THE MEASUREMENT, AFTER FRACTURE, OF THE ELONGATION AND THE REDUCTION OF CROSS-SECTION OF TENSION TEST SPECIMENS

Elongation.

20. The measurement of the elongation after fracture of tension test specimens can be made with sufficient accuracy by means of a pair of dividers and a scale. The elongation should not be reported for any tension test specimen which breaks outside the middle third of the gage length.

NOTE.—If only a few specimens are furnished for testing it is recommended that in marking the gage length for measuring elongation after fracture it be divided into eight parts, and that if a specimen breaks inside the gage length but outside the middle third of the gage length the requirement in the foregoing paragraph be waived, and the elongation be measured and reported as follows:

(1) If the specimen breaks in the middle half of the gage length (between *C*) and *G*, Figs. 10 (*a*) and (*b*)) the elongation is measured directly over the stretched gage length (Fig. 10 (*b*).

(2) If the specimen breaks between *A* and *C* (or between *G* and *I*) but nearer *B* than *A* (or nearer *H* than *I*), as shown in Fig. 10 (*c*) the elongation from *A* to *C* (or from *G* to *I*) is measured, and to this is added *twice* the measured elongation from *C* to *F* (or from *D* to *G*).

(3) If the specimen breaks within one-half a division of an end gage mark (see Fig. 10 (*d*)) the elongation from *A* to *E* (or from *E* to *I*) is measured and multiplied by 2.

The above method can be applied to specimens with any gage length, and to turned specimens as well as flat specimens.[1]

Reduction of Area.

21. The measurement of reduction of the dimensions of the cross-section of a tension test specimen may be made by the direct measurement with a micrometer of the smallest section of the fractured specimen. For round specimens this measurement can usually best be made by holding the broken pieces together in a vise or between centers and then measuring the average diameter of the smallest cross-section by means of a micrometer fitted with points so shaped that they will come in contact with the specimen at its smallest diameter.

VI. PLOTTING STRESS-STRAIN DIAGRAMS

22. A stress-strain diagram is a diagram plotted with values of stress as ordinates and values of strain as abscissas.

NOTE.—The use of the term "stress-strain diagram" is frequently extended to cover diagrams plotted with values of applied load, or applied moment, as ordinates and with values of stretch, compression, deflection, or twist as abscissas.

Stress-strain diagrams are in some cases drawn directly by an autographic attachment to the testing machine. A more usual method of procedure consists in taking a series of load readings (from the balanced scale beam of the testing machine) with corresponding readings of the strain-indicating apparatus. The term "strainometer reading" will be used to denote the reading of the strain-measuring instrument. From these readings, or from values computed from them, there is plotted a diagram with stress-indicating values (load or stress) as ordinates, and strain-indicating values (elongation or strain) as abscissas. In planning such a test it is necessary to decide on the increment of load or the increment of reading of strainometer to be used between successive readings.

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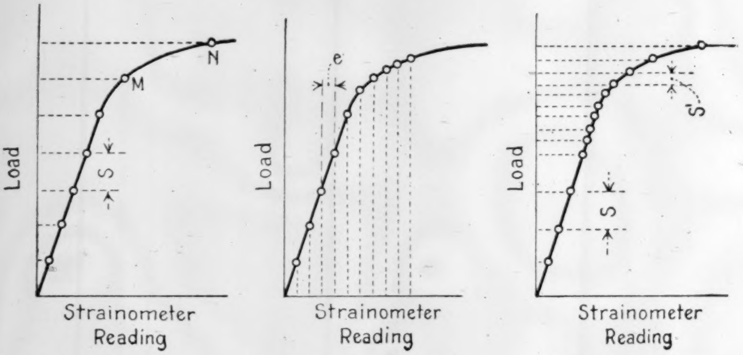
[1] It has been questioned whether this method can be used for brass specimens.—ED.

In Fig. 11 are shown three typical stress-strain diagrams. The material for all three tests is the same, and the test specimens are all of the same size, so that the diagrams should be the same. The diagram shown in Fig. 11 (*a*) is plotted from points determined by taking increments of load (*S*). In this diagram it is seen that owing to the shape of the curve, data for locating points between *M* and *N* are lacking. That particular portion of the curve (the "knee" of the curve) is the part for which it is especially desirable to locate several points on the diagram.



(*a*) With Equal Increments of Stress. (*b*) With Equal Increments of Strain. (*c*) With Two Values of Increments of Stress.

FIG. 11.—Illustrating Three Methods of Plotting Load-Deformation Curves.

In Fig. 11 (*b*) is shown a diagram plotted from points determined by taking increments of strainometer reading (*e*). It will be noted that for this diagram there are located several points near the knee of the curve, and the shape of the diagram in this important region is much more definitely determined than for the curve shown in Fig. 11 (*a*).

The custom of choosing increments of load rather than increments of strainometer reading is quite common in tests of materials and is followed because, in general, it is easier to compute increments of load than it is to compute increments of strainometer reading. An estimate of the load necessary to stress the specimen up to the knee of the curve is made and some fraction (frequently one-tenth) of this value is taken as an increment. The computation of the corresponding increment of strainometer reading is more complicated.

Sometimes the practice is followed of applying a few increments of load as determined above, and then applying load in much smaller increments (S') until the knee of the curve is passed. Fig. 11 (*c*) shows a diagram obtained in this manner. This method involves a marked increase in the number of readings necessary for a test and with unknown material there is always some danger that the knee of the curve will be reached before the use of small increments of load is begun.

The following method of choosing increments for a test is suggested: Estimate the load corresponding to the knee of the stress-strain diagram and choose a value for increment of load about one-tenth of this value. Apply this increment of load (S) once and note the corresponding change of reading for the strainometer (e). Then for the remainder of the test, use for the increment of strainometer reading a value which corresponds to some convenient interval on the scale of the strainometer, and which is approximately equal to (e).

TENTATIVE METHODS OF COMPRESSION TESTING OF METALLIC MATERIALS[1]

Serial Designation: E 9 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

These methods deal with the form and dimensions, the machining, and the testing of compression test specimens of metallic materials. Such matters as methods of taking samples from which to prepare test specimens are treated in the individual specifications for ferrous metals and for non-ferrous metals.

I. TEST SPECIMENS

1. In recommending the following specimens for use in compression tests it is not intended to exclude entirely the use of other test specimens for special materials or for special forms of material. It is, however, recommended that wherever it is feasible the specimens here recommended be used.

2. It is recommended that standard compression specimens be in the form of circular cylinders. The ends of a specimen should be plane, as nearly as can be determined by the use of a straight edge and the unaided eye. In most cases this requirement necessitates the turning or the grinding of the ends of the specimen.

3. There are recognized three classes of compression specimens for metallic materials, designated as short specimens, medium-length specimens, and long specimens, respectively. Short specimens are used for compression tests of such metals as bearing metals, which in service are used in the form of a thin plate or shell to carry load perpendicular to the surface. Medium-length specimens are used for determining the general compressive strength properties of metallic materials. Long specimens are used for determining the modulus of elasticity in compression of metallic materials.[2] In reporting the

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. F. Moore, Chairman of Sub-Committee, of Committee E-1, on Mechanical Testing of Metallic Materials, University of Illinois, Urbana, Ill.

These methods are in effect a revision of the Methods for Compression Tests of the Standard Methods of Mechanical Testing of Metallic Materials. The standard methods, which were last published under the Serial Designation: E 1 – 18, have accordingly been withdrawn.

[2] It has been suggested in discussion that the medium-length specimen may be used for determining modulus of elasticity. See discussion of the Report of Committee E-1, pp. 727 and 732.—ED.

results of a compression test, it is important that the dimensions of the test specimen be given.

4. Fig. 1 shows the proportions of the three classes of compression specimens. Suggested dimensions for compression specimens for general use are:

Short specimens: $d = 1\frac{1}{8}$ in. ± 0.01 in. (area of cross-section is approximately 1 sq. in.), $h = 1$ in.;

Medium-length specimens: $d = 1$ in. ± 0.01 in., $h = 3$ in.;[1]

Long specimens: $d = 1\frac{1}{4}$ in. ± 0.01 in., $h = 12\frac{1}{2}$ in.[1]

5. In all compression tests of metallic materials, the actual dimensions of cross-section of the test specimens shall be measured with a micrometer reading to $\frac{1}{200}$ of the dimension measured, and stresses shall be computed on the basis of the measured cross-section. It should never be assumed that the dimensions of the cross-section of the specimen are identical with the nominal dimensions.

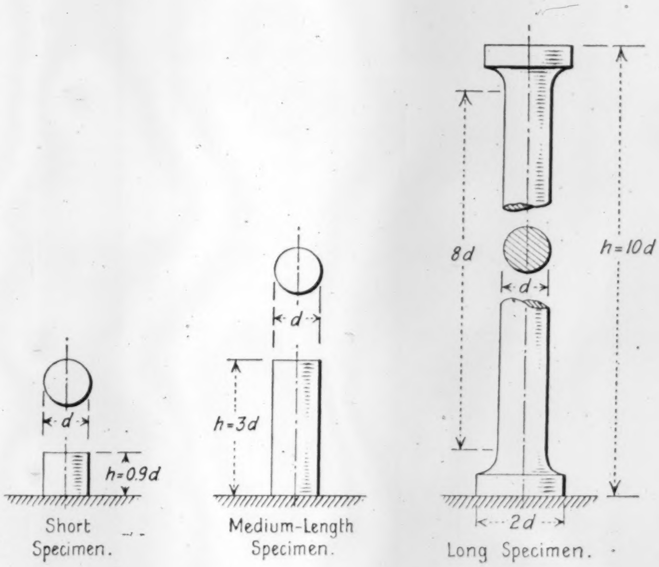

FIG. 1.

6. Specimens shall be finished so that the surfaces are smooth and free from nicks and tool marks. All ragged edges shall be smoothed.

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[1] It was suggested in discussion that for medium-length and long specimens d might be $1\frac{1}{8}$ in. Another suggestion was that d be made 0.798 in. See discussion of the Report of Committee E-1, pp. 726 and 727.—ED.

II. BEARING BLOCKS FOR COMPRESSION TEST SPECIMENS

7. Both ends of a compression test specimen shall bear on a carefully machined plane surface. The bearing blocks shall either be made of hardened steel, or shall be faced with hardened steel.

8. One end of a compression test specimen shall bear on a spherical-seated compression block.[1] Fig. 2 shows a satisfactory arrangement of compression specimens and bearing blocks. It is desirable that the spherical-seated bearing block be at the upper end of the test specimen (for specimens tested with the axis vertical). It is important that the center of the spherical surface of the spherical-seated bearing block should be in the flat face which bears on the specimen, otherwise lack of parallelism between faces of the specimen sets up a bending moment in the specimen.[2]

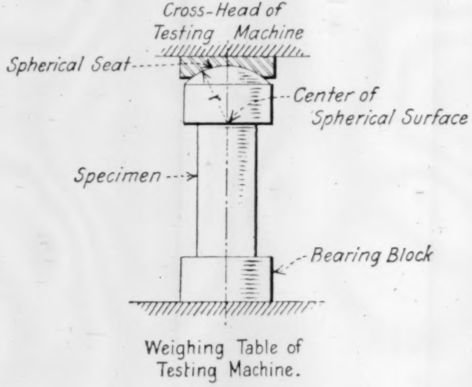
Cross-Head of Testing Machine
Spherical Seat
Center of Spherical Surface
Specimen
Bearing Block
Weighing Table of Testing Machine.

FIG. 2.

9. It should be borne in mind that the object of a spherical-seated bearing block is to give the specimen as even a distribution of initial load as is possible. Owing to friction, the spherical-seated bearing cannot be relied on to adjust itself to bending action which may occur during the test.

10. In making compression tests, care should be taken to preserve the alignment of the heads of the testing machine, and to center the specimen in the testing machine. From time to time the heads of the testing machine shall be tested for parallelism. Deviations from parallelism should not exceed 0.01 in. The movable head of the

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[1] It was suggested in discussion that this may not be necessary for carefully machined metallic specimens. See discussion of the Report of Committee E-1, pp. 727 and 732.—ED.

[2] See Mont Schuyler, "Spherical Bearings," *Proceedings*, Am. Soc. Testing Mats., Vol. XIII, p. 1004 (1913).

machine should be free from sidewise motion that is visible to the unaided eye as the machine is run at its fastest speed.

III. SPEED OF OPERATION OF TESTING MACHINE

11. In making compression tests of specimens of metallic materials the speed of the machine, by which is meant the speed of the cross-head when the machine is running idle, shall not be greater than the values given in the following table:

LENGTH OF SPECIMEN, IN.	MAXIMUM CROSS-HEAD SPEED, IN. PER MINUTE
1.00	0.05
3.00 or greater	0.10

12. In making tests to determine the elastic limit in compression of metallic materials, the cross-head speed of the testing machine shall in no case exceed the allowable speed of head for the corresponding tension test of the material, as given in Sections 15 and 16 of the Tentative Methods of Tension Testing of Metallic Materials (Serial Designation: E 8 – 24 T) of the American Society for Testing Materials.[1]

IV. THE DETERMINATION OF ELASTIC LIMIT, YIELD POINT, AND COMPRESSIVE STRENGTH

13. (*a*) The term "elastic limit" in compression is defined the same as in tension, as follows:

> *Elastic Limit.*—The greatest stress which a material is capable of withstanding without a permanent deformation remaining upon complete release of the stress.

(*b*) The same general methods for determining elastic limit, as given in Section 17 of the Tentative Methods of Tension Testing of Metallic Materials (Serial Designation: E 8 – 24 T) of the American Society for Testing Materials,[1] shall be used. For compression tests, Method II or a still more precise method seems generally suitable.

14. (*a*). The term "yield point" in compression is defined the same as in tension, as follows:

> *Yield Point.*—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

(*b*) The same methods for determining yield point as given in Section 18 of the Tentative Methods of Tension Testing of Metallic Materials (Serial Designation: E 8 – 24 T)[1] shall be used. The method by the use of dividers or by the use of a strainometer seems generally suitable for compression testing.

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[1] See p. 1081.

15. The term "compressive strength" is defined as follows:

Compressive Strength.—The maximum stress which a material that fails in compression by a shattering fracture is capable of withstanding.

No detailed discussion of methods of determining compressive strength is necessary, except to give a warning against reporting a value for compressive strength for a material which does not show well-marked fracture, but only a general flattening out of the specimen with slowly increasing load as strain is applied.[1]

V. PLOTTING STRESS-STRAIN DIAGRAMS

16. The discussion and directions given in Section 22 of the Tentative Methods of Tension Testing of Metallic Materials (Serial Designation: E 8 – 24 T)[2] apply to plotting stress-strain diagrams for compression tests.

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[1] It was pointed out in discussion that some practical arbitrary method of determining compressive strength for ductile metals would be of service. See discussion of the Report of Committee E-1, p. 727.—ED.

[2] See p. 1081.

TENTATIVE METHODS OF BRINELL HARDNESS TESTING OF METALLIC MATERIALS[1]

Serial Designation: E 10 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

The Brinell test for determining the hardness of metallic materials consists in applying a known load to the surface of the material to be tested through a hardened steel ball of known diameter. The diameter (or depth) of the resulting permanent impression in the metal is measured. The Brinell hardness number is taken as the quotient of the applied load divided by the area of the surface of the impression, which is assumed to be spherical. If P is the applied load (measured in kilograms), D is the diameter of the steel ball (measured in millimeters) and d is the diameter of the impression (measured in millimeters), then

$$\text{B.H.N.} = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

in which B.H.N. is the Brinell hardness number in kilograms per square millimeter.

If the steel ball were not deformed under the applied load and if the impression were truly spherical, then the above formula would be a general one, and any combination of applied load and size of ball could be used. As the impression is not quite a spherical surface (since there must always be some deformation of the steel ball and some recovery of form of the metal in the impression), for a standard Brinell test the size and characteristics of the ball and the magnitude of the applied load must be standardized. (A standard ball 10 mm. in diameter and a load of 3000 kg. for hard metals and 500 kg. for soft metals is standard practice. See Sections 3 and 6.

In Table I is given the Brinell hardness number corresponding to various diameters of impression for both 500 and 3000 kg. load, making it unnecessary to compute for each test the value of the Brinell Hardness Number by the above formula.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. F. Moore, Chairman of Sub-Committee, of Committee E-1, on Mechanical Testing of Metallic Materials, University of Illinois, Urbana, Ill.

These methods are in effect a revision of the Methods for Brinell Hardness Tests of the Standard Methods of Mechanical Testing of Metallic Materials. The standard methods, which were last published under the Serial Designation: E 1 – 18, have accordingly been withdrawn.

TABLE I.—BRINELL HARDNESS NUMBERS.

Steel Ball, 10 mm. in Diameter, Pressures of 500 and 3000 kg.
Prepared by the Engineering Mechanics Section, Bureau of Standards.

Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number	
	500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load
2.00	158	945	2.50	100	601	3.00	69.1	415	3.50	50.3	302	4.00	38.1	229
2.01	156	936	2.51	99.4	597	3.01	68.6	412	3.51	50.0	300	4.01	37.9	228
2.02	154	926	2.52	98.6	592	3.02	68.2	409	3.52	49.7	298	4.02	37.7	226
2.03	153	917	2.53	97.8	587	3.03	67.7	406	3.53	49.4	297	4.03	37.5	225
2.04	151	908	2.54	97.1	582	3.04	67.3	404	3.54	49.2	295	4.04	37.3	224
2.05	150	899	2.55	96.3	578	3.05	66.8	401	3.55	48.9	293	4.05	37.1	223
2.06	148	890	2.56	95.5	573	3.06	66.4	398	3.56	48.6	292	4.06	37.0	222
2.07	147	882	2.57	94.8	569	3.07	65.9	395	3.57	48.3	290	4.07	36.8	221
2.08	146	873	2.58	94.0	564	3.08	65.5	393	3.58	48.0	288	4.08	36.6	219
2.09	144	865	2.59	93.3	560	3.09	65.0	390	3.59	47.7	286	4.09	36.4	218
2.10	143	856	2.60	92.6	555	3.10	64.6	388	3.60	47.5	285	4.10	36.2	217
2.11	141	848	2.61	91.8	551	3.11	64.2	385	3.61	47.2	283	4.11	36.0	216
2.12	140	840	2.62	91.1	547	3.12	63.8	383	3.62	46.9	282	4.12	35.8	215
2.13	139	832	2.63	90.4	543	3.13	63.3	380	3.63	46.7	280	4.13	35.7	214
2.14	137	824	2.64	89.7	538	3.14	62.9	378	3.64	46.4	278	4.14	35.5	213
2.15	136	817	2.65	89.0	534	3.15	62.5	375	3.65	46.1	277	4.15	35.3	212
2.16	135	809	2.66	88.4	530	3.16	62.1	373	3.66	45.9	275	4.16	35.1	211
2.17	134	802	2.67	87.7	526	3.17	61.7	370	3.67	45.6	274	4.17	34.9	210
2.18	132	794	2.68	87.0	522	3.18	61.3	368	3.68	45.4	272	4.18	34.8	209
2.19	131	787	2.69	86.4	518	3.19	60.9	366	3.69	45.1	271	4.19	34.6	208
2.20	130	780	2.70	85.7	514	3.20	60.5	363	3.70	44.9	269	4.20	34.4	207
2.21	129	772	2.71	85.1	510	3.21	60.1	361	3.71	44.6	268	4.21	34.2	205
2.22	128	765	2.72	84.4	507	3.22	59.8	359	3.72	44.4	266	4.22	34.1	204
2.23	126	758	2.73	83.8	503	3.23	59.4	356	3.73	44.1	265	4.23	33.9	203
2.24	125	752	2.74	83.2	499	3.24	59.0	354	3.74	43.9	263	4.24	33.7	202
2.25	124	745	2.75	82.6	495	3.25	58.6	352	3.75	43.6	262	4.25	33.6	201
2.26	123	738	2.76	81.9	492	3.26	58.3	350	3.76	43.4	260	4.26	33.4	200
2.27	122	732	2.77	81.3	488	3.27	57.9	347	3.77	43.1	259	4.27	33.2	199
2.28	121	725	2.78	80.8	485	3.28	57.5	345	3.78	42.9	257	4.28	33.1	198
2.29	120	719	2.79	80.2	481	3.29	57.2	343	3.79	42.7	256	4.29	32.9	198
2.30	119	712	2.80	79.6	477	3.30	56.8	341	3.80	42.4	255	4.30	32.8	197
2.31	118	706	2.81	79.0	474	3.31	56.5	339	3.81	42.2	253	4.31	32.6	196
2.32	117	700	2.82	78.4	471	3.32	56.1	337	3.82	42.0	252	4.32	32.4	195
2.33	116	694	2.83	77.9	467	3.33	55.8	335	3.83	41.7	250	4.33	32.3	194
2.34	115	688	2.84	77.3	464	3.34	55.4	333	3.84	41.5	249	4.34	32.1	193
2.35	114	682	2.85	76.8	461	3.35	55.1	331	3.85	41.3	248	4.35	32.0	192
2.36	113	676	2.86	76.2	457	3.36	54.8	329	3.86	41.1	246	4.36	31.8	191
2.37	112	670	2.87	75.7	454	3.37	54.4	326	3.87	40.9	245	4.37	31.7	190
2.38	111	665	2.88	75.1	451	3.38	54.1	325	3.88	40.6	244	4.38	31.5	189
2.39	110	659	2.89	74.6	448	3.39	53.8	323	3.89	40.4	242	4.39	31.4	188
2.40	109	653	2.90	74.1	444	3.40	53.4	321	3.90	40.2	241	4.40	31.2	187
2.41	108	648	2.91	73.6	441	3.41	53.1	319	3.91	40.0	240	4.41	31.1	186
2.42	107	643	2.92	73.0	438	3.42	52.8	317	3.92	39.8	239	4.42	30.9	185
2.43	106	637	2.93	72.5	435	3.43	52.5	315	3.93	39.6	237	4.43	30.8	185
2.44	105	632	2.94	72.0	432	3.44	52.2	313	3.94	39.4	236	4.44	30.6	184
2.45	104	627	2.95	71.5	429	3.45	51.8	311	3.95	39.1	235	4.45	30.5	183
2.46	104	621	2.96	71.0	426	3.46	51.5	309	3.96	38.9	234	4.46	30.3	182
2.47	103	616	2.97	70.5	423	3.47	51.2	307	3.97	38.7	232	4.47	30.2	181
2.48	102	611	2.98	70.1	420	3.48	50.9	306	3.98	38.5	231	4.48	30.0	180
2.49	101	606	2.99	69.6	417	3.49	50.6	304	3.99	38.3	230	4.49	29.9	179

TABLE I—(*Continued*).

Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number	
	500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load
4.50	29.8	179	5.00	23.8	143	5.50	19.3	116	6.00	15.9	95.5	6.50	13.3	79.6
4.51	29.6	178	5.01	23.7	142	5.51	19.2	115	6.01	15.9	95.1	6.51	13.2	79.3
4.52	29.5	177	5.02	23.6	141	5.52	19.2	115	6.02	15.8	94.8	6.52	13.2	79.0
4.53	29.3	176	5.03	23.5	141	5.53	19.1	114	6.03	15.7	94.4	6.53	13.1	78.7
4.54	29.2	175	5.04	23.4	140	5.54	19.0	114	6.04	15.7	94.1	6.54	13.1	78.4
4.55	29.1	174	5.05	23.3	140	5.55	18.9	114	6.05	15.6	93.7	6.55	13.0	78.2
4.56	28.9	174	5.06	23.2	139	5.56	18.9	113	6.06	15.6	93.4	6.56	13.0	77.9
4.57	28.8	173	5.07	23.1	138	5.57	18.8	113	6.07	15.5	93.0	6.57	12.9	77.6
4.58	28.7	172	5.08	23.0	138	5.58	18.7	112	6.08	15.4	92.7	6.58	12.9	77.3
4.59	28.5	171	5.09	22.9	137	5.59	18.6	112	6.09	15.4	92.3	6.59	12.8	77.1
4.60	28.4	170	5.10	22.8	137	5.60	18.6	111	6.10	15.3	92.0	6.60	12.8	76.8
4.61	28.3	170	5.11	22.7	136	5.61	18.5	111	6.11	15.3	91.7	6.61	12.8	76.5
4.62	28.1	169	5.12	22.6	135	5.62	18.4	110	6.12	15.2	91.3	6.62	12.7	76.2
4.63	28.0	168	5.13	22.5	135	5.63	18.3	110	6.13	15.2	91.0	6.63	12.7	76.0
4.64	27.9	167	5.14	22.4	134	5.64	18.3	110	6.14	15.1	90.6	6.64	12.6	75.7
4.65	27.8	167	5.15	22.3	134	5.65	18.2	109	6.15	15.1	90.3	6.65	12.6	75.4
4.66	27.6	166	5.16	22.2	133	5.66	18.1	109	6.16	15.0	90.0	6.66	12.5	75.2
4.67	27.5	165	5.17	22.1	133	5.67	18.1	108	6.17	14.9	89.6	6.67	12.5	74.9
4.68	27.4	164	5.18	22.0	132	5.68	18.0	108	6.18	14.9	89.3	6.68	12.4	74.7
4.69	27.3	164	5.19	21.9	132	5.69	17.9	107	6.19	14.8	89.0	6.69	12.4	74.4
4.70	27.1	163	5.20	21.8	131	5.70	17.8	107	6.20	14.8	88.7	6.70	12.4	74.1
4.71	27.0	162	5.21	21.7	130	5.71	17.8	107	6.21	14.7	88.3	6.71	12.3	73.9
4.72	26.9	161	5.22	21.6	130	5.72	17.7	106	6.22	14.7	88.0	6.72	12.3	73.6
4.73	26.8	161	5.23	21.6	129	5.73	17.6	106	6.23	14.6	87.7	6.73	12.2	73.4
4.74	26.6	160	5.24	21.5	129	5.74	17.6	105	6.24	14.6	87.4	6.74	12.2	73.1
4.75	26.5	159	5.25	21.4	128	5.75	17.5	105	6.25	14.5	87.1	6.75	12.1	72.8
4.76	26.4	158	5.26	21.3	128	5.76	17.4	105	6.26	14.5	86.7	6.76	12.1	72.6
4.77	26.3	158	5.27	21.2	127	5.77	17.4	104	6.27	14.4	86.4	6.77	12.1	72.3
4.78	26.2	157	5.28	21.1	127	5.78	17.3	104	6.28	14.4	86.1	6.78	12.0	72.1
4.79	26.1	156	5.29	21.0	126	5.79	17.2	103	6.29	14.3	85.8	6.79	12.0	71.8
4.80	25.9	156	5.30	20.9	126	5.80	17.2	103	6.30	14.2	85.5	6.80	11.9	71.6
4.81	25.8	155	5.31	20.9	125	5.81	17.1	103	6.31	14.2	85.2	6.81	11.9	71.3
4.82	25.7	154	5.32	20.8	125	5.82	17.0	102	6.32	14.1	84.9	6.82	11.8	71.1
4.83	25.6	154	5.33	20.7	124	5.83	17.0	102	6.33	14.1	84.6	6.83	11.8	70.8
4.84	25.5	153	5.34	20.6	124	5.84	16.9	101	6.34	14.0	84.3	6.84	11.8	70.6
4.85	25.4	152	5.35	20.5	123	5.85	16.8	101	6.35	14.0	84.0	6.85	11.7	70.4
4.86	25.3	152	5.36	20.4	123	5.86	16.8	101	6.36	13.9	83.7	6.86	11.7	70.1
4.87	25.1	151	5.37	20.3	122	5.87	16.7	100	6.37	13.9	83.4	6.87	11.6	69.9
4.88	25.0	150	5.38	20.3	122	5.88	16.7	99.9	6.38	13.8	83.1	6.88	11.6	69.6
4.89	24.9	150	5.39	20.2	121	5.89	16.6	99.5	6.39	13.8	82.8	6.89	11.6	69.4
4.90	24.8	149	5.40	20.1	121	5.90	16.5	99.2	6.40	13.7	82.5	6.90	11.5	69.2
4.91	24.7	148	5.41	20.0	120	5.91	16.5	98.8	6.41	13.7	82.2	6.91	11.5	68.9
4.92	24.6	148	5.42	19.9	120	5.92	16.4	98.4	6.42	13.6	81.9	6.92	11.4	68.7
4.93	24.5	147	5.43	19.9	119	5.93	16.3	98.0	6.43	13.6	81.6	6.93	11.4	68.4
4.94	24.4	146	5.44	19.8	119	5.94	16.3	97.7	6.44	13.5	81.3	6.94	11.4	68.2
4.95	24.3	146	5.45	19.7	118	5.95	16.2	97.3	6.45	13.5	81.0	6.95	11.3	68.0
4.96	24.2	145	5.46	19.6	118	5.96	16.2	96.9	6.46	13.4	80.7	6.96	11.3	67.7
4.97	24.1	144	5.47	19.5	117	5.97	16.1	96.6	6.47	13.4	80.4	6.97	11.3	67.5
4.98	24.0	144	5.48	19.5	117	5.98	16.0	96.2	6.48	13.4	80.1	6.98	11.2	67.3
4.99	23.9	143	5.49	19.4	116	5.99	16.0	95.9	6.49	13.3	79.8	6.99	11.2	67.0

I. APPARATUS

Micrometer Microscope.

1. The micrometer microscope or other measuring device used for the measurement of the diameter of impression shall be capable of measuring the diameter of the impression within 0.01 mm. (0.0004 in.).

Brinell Ball.

2. (*a*) The balls used in Brinell hardness testing shall be of hardened steel.

(*b*) A ball to be suitable for use shall not show a permanent change in diameter greater than 0.0025 mm. (0.0001 in.) when pressed with a force of 3000 kg. against a piece of steel having a Brinell hardness number of 500 or greater.[1]

(*c*) If a ball is used in a test of a specimen which shows a Brinell hardness number greater than 500, the ball shall be remeasured after the test. Should the ball show a permanent change in diameter greater than that permitted in Paragraph (*b*), the ball shall be unsuitable for further use in a standard test.[1]

Size of Standard Ball.

3. The standard ball for Brinell hardness testing shall be 10 mm. (0.3937 in.) in diameter with a deviation from this value of not more than 0.0025 mm. (0.0001 in.) in any diameter.

For testing very small specimens or very thin specimens it is sometimes necessary to make Brinell hardness tests with a ball less than 10 mm. in diameter. For such tests (which are not to be regarded as standard Brinell tests) the relation between applied load, P, measured in kilograms, and diameter of ball, D, measured in millimeters, should be

$$P = 3000 \frac{D^2}{10^2} = 30\ D^2 \text{ for iron and steel}$$

$$\text{and } P = 500 \frac{D^2}{10^2} = 5\ D^2 \text{ for brass, bronze and soft metals in general.}$$

For extremely soft metals the relation $P = D^2$ may be used.

Balls differing in size from the standard 10-mm. ball shall conform to the requirements for the material and the tolerance in size of diameter as specified for the standard ball.

II. TEST SPECIMENS

Specimens used in Brinell hardness testing vary greatly in form since it is frequently desirable to make the impression upon a part to be used in the finished product rather than upon a sample test specimen.

Thickness of Specimen.

4. The thickness of the piece tested shall be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the impression.[2]

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[1] It was pointed out in discussion that it probably is not feasible to obtain balls meeting the above requirements and a modification of the above was suggested. See discussion of the Report of Committee E-1, p. 728.—ED.

[2] It was suggested in discussion that the additional requirement be made that the thickness of specimen be at least 10 times the depth of impression. See discussion of the Report of Committee E-1, p. 730—ED.

Finish of Specimen.

5. The surface on which the impression is to be made shall be filed, ground, machined, or polished with emery paper so that the edge of the impression shall be clearly enough defined to permit of the measurement of the diameter within 0.01 mm. (0.0004 in.).

III. APPLICATION AND MAGNITUDE OF LOAD

Magnitude.

6. The load in the standard Brinell test shall be 3000 kg. for iron and steel and 500 kg. for brass, bronze and soft metals generally.

NOTE.—For extremely soft metals a load of 100 kg. is sometimes used. If for any reason it is necessary to use loads differing from those specified above, the load used should be specifically stated in the test report, conveniently as a subscript of the hardness numeral.

Application.

7. (*a*) The load shall be applied steadily to the specimen without jerk.

(*b*) The load shall be applied for at least 10 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals.[1]

(*c*) The center line of the applied load shall be far enough from any edge of the specimen so that when a straight-edge is applied to the edge after the load has been applied, the eye can detect no bulge in the edge due to the load and the resulting impression.

IV. MEASUREMENT OF IMPRESSION

8. In the standard Brinell hardness test the diameter of the impression shall be measured.

Measurement of Diameter of Impression.

9. When a micrometer microscope is used to measure the diameter of the impression the sharpness of definition of the edge of the impression can be increased by the use of a movable lamp for illuminating the specimen, placing the lamp so that the contrast of light and shade will bring first one edge of the impression, then the other into sharp definition. In testing very hard material, the sharpness of definition of the impression can be somewhat increased by the use of a ball lightly etched with nitric acid, or by the use of some pigment, such as Prussian blue, on the ball. In testing material in which there is considerable recovery of shape, the material may first be coated with a dull black pigment, such as drawing ink or a mixture of graphite and alcohol. The edge of the impression is rendered clear on a surface so coated.

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[1] It was suggested in discussion that for magnesium and magnesium alloys the minimum time of application be 2 minutes. It was also suggested that for any given soft metal a definite time for holding the load be specified rather than a minimum time. See discussion of the Report of Committee E-1, pp. 729 and 730.—ED.

BRINELL HARDNESS TESTS IN WHICH DEPTH OF IMPRESSION IS MEASURED IN PLACE OF DIAMETER

When it is necessary to make Brinell hardness tests very rapidly, as is sometimes the case when the Brinell test is used as a control test for the output of a heat-treating furnace, the depth of impression under load, or after the release of load, can be measured more expeditiously than the diameter of impression. The depth of impression is usually determined from the motion of the plunger carrying the ball. This method of determining Brinell hardness is not to be regarded as a standard method, and when requirements of speed necessitate its use, the Brinell hardness number should not be determined from the geometrical relation of depth of impression to diameter, based on the assumption that the impression has a spherical surface. In such tests the relation between the Brinell hardness number and depth of impression may be determined with a fair degree of accuracy from tests on specimens of material of different degrees of hardness, several impressions being made on each specimen, and the depth under load, or the depth on release of load, and the diameter of impression after release of load being measured for each impression. By the use of a diagram or by interpolation, a table giving the Brinell hardness number for a given depth of impression can be prepared.

V. CALIBRATION OF BRINELL HARDNESS TESTING APPARATUS

10. A load-measuring device which is in common use for Brinell hardness testing machines involves the measurement of fluid pressure on a piston of known diameter, working in a cylinder with so perfect a fit that packing is not necessary. To this piston is attached the ball. Other load-measuring devices use combinations of weights and levers. The use of dead weights acting on a small piston is to be preferred to the ordinary Bourdon gage for measuring the intensity of fluid pressure.

11. The load-measuring device of a Brinell hardness testing machine may be calibrated by the use of dead weights, or by the use of dead weights and proving levers, in the manner described in the Standard Methods of Verification of Testing Machines (Serial Designation: E 4) of the American Society for Testing Materials.[1]

12. The load-measuring device of a Brinell hardness testing machine may be calibrated by making a series of impressions on specimens of different degrees of hardness, measuring the diameters of the impressions, making a second series of impressions by the use of any standardized testing machine and standard steel ball, and, using the same measuring device as for the first series of impressions, measuring the diameters of this second series of impressions. The error of the machine under calibration can be determined by the relative average

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[1] 1924 Book of A.S.T.M. Standards. See also J. L. Jones and C. H. Marshall, "A New Method for Calibrating Brinell Hardness Testing Machines," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 392 (1920).

values of the hardness numbers determined by its use and by the use of the standardized testing machine.

13. When the above companion-impression method of calibrating a Brinell hardness testing machine is used it is recommended that the specimens used be approximately 1 by 1 by 12 in. in size, and that specimens with as wide a range of hardness as is feasible be used. It is recommended that impressions made by the machine under calibration be spaced about 2.5 in. apart along the specimen, and that the impressions made by the standardized testing machine be spaced alternately along the length of the specimen with the impressions made by the machine under calibration.

14. If any determination of hardness, either for the machine under calibration or for the standard machine differs by more than 2 per cent from the mean of the four determinations made with that machine it is recommended that such determination be discarded. If two determinations differ more than 2 per cent from the mean the whole series should be discarded.

15. A Brinell hardness testing machine is acceptable for general use if its load-measuring device is correct within 3 per cent.

16. The micrometer microscope or other device for measuring diameter of impression may be calibrated by using it to measure lengths on a standard steel or glass scale. The eye piece of a micrometer microscope should be adjusted so that throughout the range covered the error of reading does not exceed 0.01 mm.

TENTATIVE METHOD OF VERIFICATION OF TESTING MACHINES BY MEANS OF AN ELASTIC CALIBRATION BAR[1]

Serial Designation: E 4 – 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to annual revision.

ISSUED, 1924

1. In this method the testing machine to be verified is tested by comparing its load indications with the amount of elastic deformation of a calibration bar, the deformation being measured with a delicate strainometer.

2. The calibration bar may be either a bar tested in tension or in compression and it shall be fitted with spherical-seated shackles or with a spherical-seated bearing block to insure as nearly axial loading as is possible. The arrangement shown in Fig. 1 or Fig. 2 is suggested for tension bars and the arrangement shown in Fig. 3 is suggested for compression bars.

3. (*a*) The calibration bar shall be of such size that under the greatest load for which the bar is to be used (called its full load) the stress on any cross-section will not be more than 80 per cent of the elastic limit of the material, as determined in accordance with Method II for the Determination of Elastic Limit as described under the definition of the term "Elastic Limit" of the Tentative Definitions of Terms Relating to Methods of Testing (Serial Designation: E 6 – 24 T) of the American Society for Testing Materials[2] on a test specimen cut from the end of the bar after its final heat treatment.

(*b*) Before the calibration bar is used for verification purposes, it shall be loaded to its full load at least six times, and between successive loadings it shall be heated to a temperature of 100° C. (212° F.) for a period of thirty minutes or shall be allowed to rest for a period of 24 hours. The object of this treatment is to adjust the bar to its bearings and to relieve internal strain.

4. The *loading range* of a calibration bar is the range of indicated loads for which the bar gives results within specified tolerances.

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[1] This Tentative Method, when adopted as standard, will become a part of the present **Standard** Methods of Verification of Testing Machines (Serial Designation: E 4 – 24), 1924 Book of **A.S.T.M.** Standards.

Criticisms of this Tentative Method are solicited and should be directed to Mr. H. F. Moore, Chairman of Sub-Committee, of Committee E-1, on Mechanical Testing of Metallic Materials, University of Illinois, Urbana, Ill.

[2] See p. 1109.

Obviously, the loading range may not include loads either greater than the largest load or less than the smallest load applied in verifying the calibration bar.

5. (*a*) The loading range of a calibration bar shall be determined by verifying its indications by the use of standard weights or by standard weights and proving levers. In verifying the indications of the bar, an initial load of 1 per cent of its full load shall first be applied. All changes of strainometer reading and of applied load shall be reckoned from the readings at this initial load. Successive loads shall be applied, a recommended series of loads being 10, 20, 50 and 100 per cent of the full load of the bar. Such a series shall be applied to the bar at least five times to determine the relation of applied load to strainometer reading, the shackles or bearing blocks being readjusted before each application of the series.

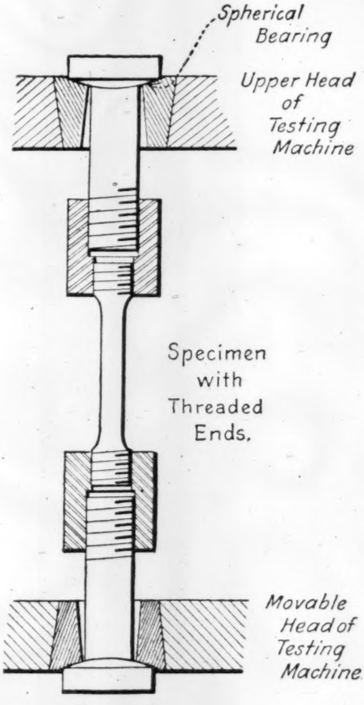
Spherical Bearing
Upper Head of Testing Machine
Specimen with Threaded Ends.
Movable Head of Testing Machine

FIG. 1.

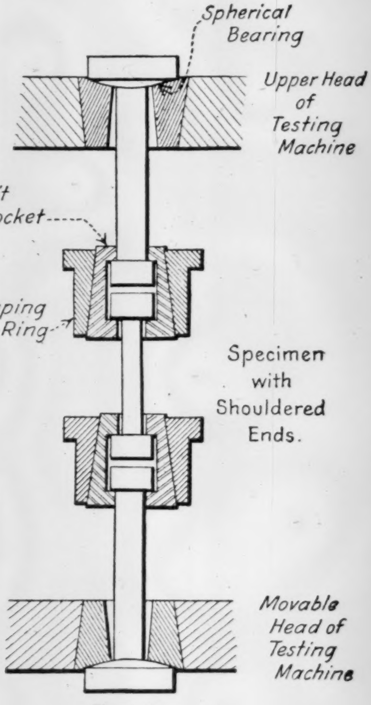
Spherical Bearing
Upper Head of Testing Machine
Split Socket
Solid Clamping Ring
Specimen with Shouldered Ends.
Movable Head of Testing Machine

FIG. 2.

(*b*) The average of the five (or more) strainometer readings obtained in this way shall be taken for each load applied. The average of the differences (taken without regard to algebraic sign) between the individual strainometer readings for any load and the mean reading for that load constitutes the average deviation for that load. The lowest value of load for which the average deviation is not greater than 0.5 per cent of the strain for that load is the lower limit of the loading range of the calibration bar.

6. The strainometer shall be permanently attached to the calibration bar and shall be so designed as to indicate the average elongation or compression of the bar. The strainometer shall be sufficiently sensitive to indicate a change of 0.25 per cent of the minimum load in the loading range of the bar.

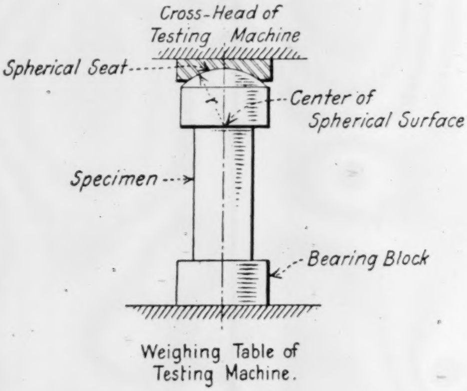
Cross-Head of Testing Machine
Spherical Seat
Center of Spherical Surface
Specimen
Bearing Block
Weighing Table of Testing Machine.

FIG. 3.

7. In using the calibration bar it is important that just previous to taking any reading, including the initial reading of a series, there shall be no reversal in the direction of motion of the indicating mechanism of the strainometer, because such reversal may introduce error due to backlash in the instrument. That is, when taking readings for a series of increasing loads the load should be brought up to each predetermined test load, and when taking readings for a series of decreasing loads the load should be brought down to each predetermined test load.

8. The calibration bar shall be used at a temperature between 10 and 32° C. (50 and 90° F.).

TENTATIVE DEFINITIONS OF TERMS RELATING TO METHODS OF TESTING[1]

Serial Designation: E 6 - 24 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and is subject to revision.

ISSUED, 1923; REVISED, 1924

Stress.—The intensity (measured per unit area) of the internal distributed forces or components of force which resist a change in the form of a body. Stress is measured in force per unit area (pounds per square inch, kilograms per square millimeter, etc.).[2]

NOTE.—In examining the definitions given in various authoritative text-books two definitions of the term "stress" were found. Text-books in physics and some European text-books in mechanics of materials gave a definition substantially as above. American text-books in engineering mechanics define stress as a *force*, measured in *pounds*. They call the intensity of force (pounds per square inch) "unit stress," "intensity of stress," or "fiber stress." This use of the term stress is illustrated by the "stress sheet" of the bridge engineer which gives *forces*, measured in pounds.

In view of the fact that even in engineering text-books the term "stress" is often used to denote intensity of force per unit of area, and in view of the fact that the physicists' definitions involve somewhat simpler terms, the physicists' definitions have been followed in these standards.

While it is important to have a clear definition for the term "stress" it is even more important to keep clearly in mind the *units* used in computations and test data for materials of construction. In fact, if the units are always given, there can be no misunderstanding as to the sense in which the term "stress" is used.

There are three kinds of stress: tensile, compressive, and shearing. Flexure involves the combination of tensile stress and compressive stress. Torsion involves shearing stress.

Strain.—The change per unit of length in a linear dimension of a body, which change accompanies a stress. Strain is measured in inches per inch of length (millimeters per millimeter).

NOTE.—In American engineering text-books the term "strain" is used in the sense of total deformation and is measured in inches. Change of dimension per unit length is called "unit-strain," or "unit deformation." As in the consideration of the term "stress," the definitions given in text-books in physics have been followed.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. H. F. Moore, Chairman of Sub-Committee, of Committee E-1, on Mechanical Testing of Metallic Materials, University of Illinois, Urbana, Ill.

These definitions are in effect a revision of the definitions of terms appearing in the Standard Methods of Mechanical Testing of Metallic Materials. The standard methods, which were last published under the Serial Designation: E 1 - 18, have accordingly been withdrawn.

[2] It was suggested in discussion that the statement be added that it is customary to compute stress on the basis of the original dimensions of cross-section of the body.—ED.

Under tensile stress or compressive stress, strain is measured along the dimension under consideration. Shearing strain is measured at right angles to the dimension under consideration. In torsion tests, which involve shearing stress, it is customary to measure the angle of twist, which may be translated into terms of strain.

A Stress-Strain Diagram.—A diagram plotted with values of stress as ordinates and values of strain as abscissas.

NOTE.—The use of the term stress-strain diagram is frequently extended to cover diagrams plotted with values of applied load, or applied moment as ordinates, and with values of stretch, compression, deflection, or twist as abscissas.

Fig. 1 is an example of a stress-strain diagram.

Stress-strain diagrams are in some cases drawn directly by an autographic attachment to the testing machine. A more usual method of procedure consists in taking a series of load readings (from the balanced scale beam of the testing machine) with corresponding readings of the strain-indicating apparatus (extensometer, compressometer, deflectometer, or torsion indicator). The term "strainometer reading" will be used to denote the reading of any strain-measuring instrument. From these readings, or from values computed from them, there is plotted a diagram with stress-indicating values (load, flexural moment, twisting moment, or stress) as ordinates, and strain-indicating values (elongation, shortening, deflection, twist, or strain) as abscissas. In planning such a test it is necessary to decide on the increment of load or the increment of reading of strainometer to be used between successive readings.

In Fig. 2 are shown three typical stress-strain diagrams. The material for all three tests is the same, and the test specimens are all of the same size, so that the diagrams should be the same. The diagram shown in Fig. 2 (*a*) is plotted from points determined by taking increments of load (S). In this diagram it is seen that owing to the shape of the curve, data for locating points between M and N are lacking. That particular portion of the curve (the "knee" of the curve) is the part for which it is especially desirable to locate several points on the diagram.

In Fig. 2 (*b*) is shown a diagram plotted from points determined by taking increments of strainometer reading (e). It will be noted that for this diagram there are located several points near the knee of the curve, and the shape of the diagram in this important region is much more definitely determined than for the curve shown in Fig. 2 (*a*).

The custom of choosing increments of load rather than increments of strainometer reading is quite common in tests of materials and is followed because, in general, it is easier to compute increments of load than it is to compute increments of strainometer reading. An estimate of the load necessary to stress the specimen up to the knee of the curve is made and some fraction (frequently one-tenth) of this value is taken as an increment. The computation of the corresponding increment of strainometer reading is more complicated.

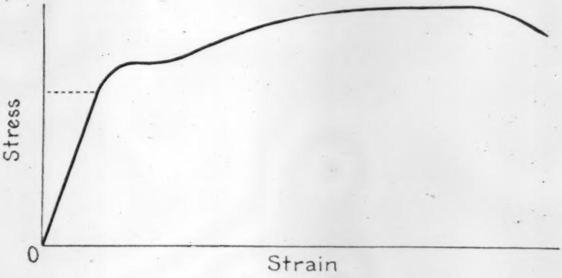
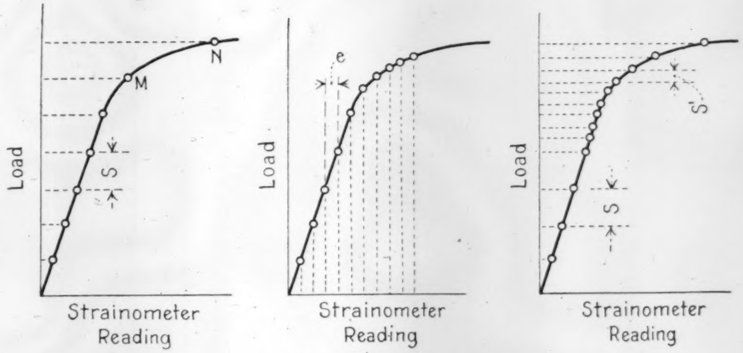


FIG. 1.—A Typical Stress-Strain Diagram.


Load
N
M
S
Strainometer Reading
Load
e
Strainometer Reading
Load
S'
S
Strainometer Reading

(*a*) With Equal Increments of Stress.

(*b*) With Equal Increments of Strain.

(*c*) With Two Values of Increments of Stress.

FIG. 2.—Illustrating Three Methods of Plotting Load-Deformation Curves.

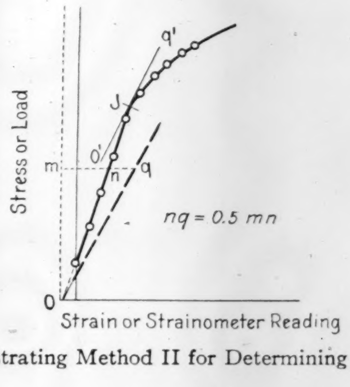

q'
J
0'
m
n
q
Stress or Load
nq = 0.5 mn
0
Strain or Strainometer Reading

FIG. 3.—Illustrating Method II for Determining Elastic Limit.

Sometimes the practice is followed of applying a few increments of load as determined above, and then applying load in much smaller increments (S') until the knee of the curve is passed. Fig. 2 (c) shows a diagram obtained in this manner. This method involves a marked increase in the number of readings necessary for a test and with unknown material there is always some danger that the knee of the curve will be reached before the use of small increments of load is begun.

The following method of choosing increments for a test is suggested: Estimate the load corresponding to the knee of the stress-strain diagram and choose a value for increment of load about one-tenth of this value. Apply this increment of load (S) once and note the corresponding change of reading for the strainometer (e). Then for the remainder of the test, use for the increment of strainometer reading a value which corresponds to some convenient interval on the scale of the strainometer, and which is approximately equal to (e).

Elastic Limit.—The greatest stress which a material is capable of withstanding without a permanent deformation remaining upon complete release of the stress.

NOTE.—Since experience does not indicate any appreciable difference between the elastic limit and the limit of proportionality of stress to strain (sometimes called the proportional limit), the determination of the stress at the limit of proportionality of stress to strain is regarded as an accurate determination of the elastic limit.

It is obvious that the values obtained in tests for determining the elastic limit will depend on the delicacy of methods and instruments used. It becomes necessary, therefore, that in any test the method used in obtaining the elastic limit be clearly stated. The following methods are in common use for determining a value designated as the elastic limit:

Method I. (For tension tests only, proposed by Committee A-1 on Steel, and embodied in a number of specifications for steel.) The elastic limit shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer may then be removed from the specimen and the test continued to determine the tensile strength.

Method II (proposed by the late J. B. Johnson) is a somewhat more delicate method for locating the elastic limit than is Method I. In Method II, the elastic limit shall be taken as that stress at which the rate of deformation is 50 per cent greater than the initial rate of deformation. A stress-strain diagram is necessary for determining the elastic limit by Method II. Fig. 3 illustrates the use of Method II. The initial rate of deformation is given by the ratio $mn : Om$. $nq = 0.5\ mn$, $mq = 1.5\ mn$, and the slope of Oq represents a rate of deformation 50 per cent greater than the initial rate. $O'q'$ is drawn parallel to Oq and tangent to the stress-strain diagram. The point of tangency J locates the elastic limit. In using Method II the same precautions should be observed in attaching the strainometer as for the determination of the elastic limit by Method I. Method II, if used for tension tests of metals, gives lower values for the elastic limit than does Method I. It is recommended that in using Method II for tension tests the strainometer be of such sensitiveness that it will indicate a change of strain of 0.0001 in. per inch of gage length (0.0001 mm. per millimeter of gage length) and that a corresponding degree of sensitiveness be required for strainometers used for compression tests, for flexure tests, and for torsion tests.

When it is desired to determine the elastic limit with a high degree of precision, it is suggested that the experimenter devise his own procedure, and in reporting his results describe the procedure in detail, including a statement of the limits of sensitiveness of the apparatus used and of the procedure used in plotting the stress-strain diagram from which the determination of elastic limit is made. It is to be remembered that the accurate determination of the elastic limit requires the use of accurate and sensitive instruments and the use of accurate methods of plotting test data.

Yield Point.—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

NOTE.—Some metals do not show a clearly defined yield point.

Two methods are in use for determining the yield point: (I) The "drop of the beam" method, and (II) the method by use of dividers. In Method I, load is applied to the specimen at a steady rate of increase and the operator keeps the beam in balance by running out the poise at a steady rate. At the yield point the increase of load stops, but the operator, running out the poise at a steady rate, runs it a trifle beyond the balance position, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device there is a sudden halt of the load-indicating pointer, corresponding to the drop of the beam. The load at the "halt" or the "drop" is recorded, and the corresponding stress is taken as the yield point. This method of determining the yield point requires only one man to conduct a test.

In Method II for determining the yield point, one observer keeps the beam of the testing machine balanced, and another observer with a pair of dividers watches for visible elongation between two gage marks on the specimen. When visible stretch is observed the fact is at once reported to the man operating the beam of the testing machine, the load at that instant is noted, and the stress corresponding to the load is taken as the yield point. When a strainometer[1] is used in place of dividers a deformation of 0.01 in. over a gage length of 2 in. shall be regarded as indicating the yield point.

Tensile Strength.—The maximum tensile stress which a material is capable of withstanding.

NOTE.—In practice, it is considered to be the maximum stress carried by a specimen representing the material in a tension test to rupture, under definite prescribed conditions.

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[1] The determination of yield point with a strainometer is sometimes made in tests on non-ferrous metals.

Compressive Strength.—The maximum stress which a material that fails in compression by a shattering fracture is capable of withstanding.

Modulus of Elasticity.—The ratio, within the elastic limit of a material, of stress to corresponding strain.

NOTE.—As there are three kinds of stress, so are there three moduli of elasticity for any material: the modulus in tension, the modulus in compression, and the modulus in shear. The value of the modulus of elasticity in tension is nearly the same, for most metals, as the value of the modulus of elasticity in compression. The value of the modulus of elasticity in shear is smaller than the value of the modulus of elasticity in tension. The modulus of elasticity is expressed in pounds per square inch (kilograms per square millimeter).

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative revision of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticisms, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the officer of the appropriate committee, whose name and address appear in the footnote in connection with each revision.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS

B. NON-FERROUS METALS

STANDARD SPECIFICATIONS FOR LAKE COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS

(SERIAL DESIGNATION: B 4 – 13)[1]

Section 4 (a).—Change the first sentence in the second paragraph to read as follows by the addition of the italicized figures and the omission of those in brackets:

> "Low Resistance Lake wire bars shall have a resistivity not to exceed [0.15535] *0.15436* international ohms per meter-gram at 20° C. (annealed)."

Section 5 (a).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

> "Low Resistance Lake copper shall have a purity of at least [99.880] *99.900* per cent as determined by electrolytic assay, silver being counted as copper."

Section 5 (b).—Change the first sentence to read as follows by the addition of the italicized figures and the omission of those in brackets:

> "High Resistance Lake copper shall have a purity of at least [99.880] *99.900* per cent, copper, silver, and arsenic being counted together."

Section 9.—Change the second paragraph from its present form: namely,

> "In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately ½ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final."

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[1] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

to read as follows:

"In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five holes, approximately ½ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

"The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

"Each party shall make an analysis by the Standard Method of Battery Assay of Copper (B 34 – 20) of the American Society for Testing Materials and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final."

STANDARD SPECIFICATIONS FOR ELECTROLYTIC COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS

(SERIAL DESIGNATION: B 5 – 13)[1]

Section 3 (a).—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

"*Metal Content.*—The copper in all shapes shall have a purity of at least [99.880] *99.900* per cent, as determined by [electrolytic assay] *the A.S.T.M. Standard Method of Battery Assay of Copper (B 34 – 20)*, silver being counted as copper."

Section 3 (b).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

"*Resistivity.*—All wire bars shall have a resistivity not to exceed [0.15535] *0.15436* international ohms per meter-gram at 20° C. (annealed); all ingots and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed)."

Section 7.—Change the second paragraph from its present form: namely,

"In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately ½ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final."

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[1] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

to read as follows:

"In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five holes approximately ½ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

"The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

"Each party shall make an analysis and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final."

STANDARD SPECIFICATIONS FOR LIGHT ALUMINUM CASTING ALLOYS

(SERIAL DESIGNATION: B 26 – 21)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Light Aluminum Casting Alloys (B 26 – 24 T)"[2] is intended to replace the present standard specifications.

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[1] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., 67 Wall St., New York City.

[2] See p. 785.

C. CEMENT, LIME, GYPSUM AND CLAY PRODUCTS

STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT

(SERIAL DESIGNATION: C 9 – 21)[1]

A revision in the form of a separate tentative specification entitled "Specifications and Tests for Compressive Strength of Portland-Cement Mortars (C 9 – 16 T)"[2] is intended to become a part of the present standard specifications.

STANDARD SPECIFICATIONS FOR CEMENT-CONCRETE SEWER PIPE

(SERIAL DESIGNATION: C 14 – 24)[3]

Section 1.—Add the following footnote:

"*Caution.*—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction."

STANDARD SPECIFICATIONS FOR FIRE TESTS OF MATERIALS AND CONSTRUCTION

(SERIAL DESIGNATION: C 19 – 18)[4]

Section 2 (*a*).—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

"The temperature fixed by the curve shall be deemed to be the average [true] temperature [of the furnace gases as] obtained from the readings of several thermo-couples (not less than three) symmetrically disposed and distributed [in such a manner as] to show [temperatures of the gases] *the temperature* near all parts of the sample, *said thermo-couples being enclosed in sealed porcelain tubes of $\frac{3}{4}$-in. outside diameter and $\frac{1}{8}$-in. wall thickness, the immersion of the couple in the furnace chamber to be not less than 12 in. Other types of protecting tubes or pyrometers may be used, that under test conditions give the same indications as the above standard within the limit of accuracy that applies for furnace temperature measurements.*

For greater difference of design and size the time temperature curve followed shall be modified to give an exposure equal to that obtained by using the standard pryometer and curve above described.

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[1] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. R. B. Young, Secretary of Committee C-1 on Cement, Hydro-Electric Power Commission of Ontario, 8 Strachan Ave., Toronto, Ontario, Canada.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 599 (1920).

[3] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. F. B. Lysle, Secretary of Committee C-4 on Clay and Cement-Concrete Sewer Pipe, 900 City Hall, Philadelphia, Pa.

[4] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. R. P. Miller, Secretary of Committee C-5 on Fireproofing, 25 W. Forty-fifth St., New York City.

Section 6.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

"The fire test on the sample with its applied load, if any, shall be continued until failure occurs, or until it has withstood the test conditions for a period equal to [1¼ times that for which classification is desired] *that herein specified in the Conditions of Acceptance for the given type of construction.*"

TABLE I

Parts of Structure.	Type of Protection.	Size of Hose Nozzle, in.	Water Pressure at Nozzle, lb.	Time of Application min.
Floors and Roofs	4 hour	1 1/8	50	[10] *7*
	2 "	1 1/8	50	[5] *4*
	1 "	1 1/8	50	[2.5] *2*
	1/2 "	1 1/8	30	1
	1/4 "	1 1/8	[15] *30*	1
Walls, [Columns] and Partitions	4 "	1 1/8	50	5
	2 "	1 1/8	30	3
	1 "	1 1/8	30	2.5] *2*
	1/2 "	1 1/8	30	1
	1/4 "	1 1/8	[15] *30*	1
Columns	*4* "	*1 1/8*	*50*	*3*
	2 "	*1 1/8*	*30*	*2*
	1 "	*1 1/8*	*30*	*1 1/2*
	1/2 "	*1 1/8*	*30*	*1*
	1/4 "	*1 1/8*	*30*	*1/2*

Section 7.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

"A second test with duplicate sample shall be made to determine the effect of a hose stream on a sample under fire test, the water being applied at the end of a period equal to [three-fourths] *one-half* of that for which classification is desired, but not later than one hour after the beginning of the test; except that for classification periods of one-half hour or less the fire stream test may be omitted.

Table I.—Change Table I, referred to in Section 8, to read as indicated in the accompanying Table I by the addition of the italicized word and figures and the omission of the word and figures in brackets.

Section 9.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets, changing the side heading from "Loading" to "Loading and Additional Tests":

"For any material or construction intended to carry load other than its own weight, the full [rated safe] working load shall be applied during the entire fire test, also during the fire stream test. After completion of the fire stream test, the sample shall be subjected to [excess loading as prescribed under specifications for the different structural parts] *additional tests as herein specified in the Conditions of Acceptance for the given type of construction.*"

Add a new Section 10, under the sub-division "Conduct of Fire Tests," entitled "Time of Testing," to read as follows:

"The material or construction shall not be tested until a large proportion of its final strength has been attained and the excess of free water has been given off. Where this cannot be attained within 40 days, artificial drying with air temperature not exceeding 100° F. shall be used."

Section 10.—Renumber the present Section 10 to Section 12.

Section 11.—Omit this section reading as follows:

"The floor or roof may be tested as soon after construction as desired, but within 40 days. Artificial drying will be allowed if desired."

Section 12.—Transfer this section, placing it under the sub-division "Conduct of Fire Tests," renumbering it Section 11.

Section 14.—Change the side heading to read "Conditions of Acceptance."

Section 14 (a).—Change to read as follows by the omission of the words in brackets:

"The floor or roof shall have sustained safely the full [rated safe] working load during the fire test without passage of flame for a period equal to 1¼ times that for which classification is desired."

Section 18.—Change the side heading to read "Conditions of Acceptance."

Add five new sections relating to column tests to read as follows:

19. *Size of Sample.*—For column tests, the length of the column exposed to fire shall approximate the clear length of the member in the structure, and for building columns shall be not less than 9 ft. The outside lateral dimensions shall be the minimum for which classification is desired. The details of construction, and exposed connections and protection, if any, shall be applied according to the methods of acceptable field practice.

20. *Loading.*—During the fire test and the fire and water test, a constant working load shall be applied to the column, calculated according to the governing design regulations. Provisions shall be made for transmitting the load to the exposed portion without unduly increasing the effective column length.

21. *Measurements.*—Measurements shall be made of the expansion or depression at the head of the column and determination of the period of expansion. Such other measurements shall be made of deformation and of temperature of the column as will give the most useful information for the given column type.

22. *Position of Nozzle.*—The distance of the nozzle from the column during the application of water shall be 20 ft., the water being applied in succession, as uniformly as possible, over the full height on three of its sides.

23. *Conditions of Acceptance.*—The test shall not be regarded as successful unless the following conditions are met:

(*a*) The column shall have sustained the full working load during the fire test for a period equal to —[1] times that for which classification is desired.

(*b*) The column shall have sustained the full working load during the fire stream test as prescribed in Sections 7 and 8, and after its completion and when cold shall sustain a total load equal to the dead load component plus twice the live load component of its design working load.

(*c*) After the fire stream test the column when dry shall withstand, under working load, a fire test of duration equal to —[1] of the period for which classification is desired, but not exceeding one hour.

D. MISCELLANEOUS MATERIALS

STANDARD SPECIFICATIONS FOR BROKEN SLAG FOR WATERBOUND BASE AND WEARING COURSE

(SERIAL DESIGNATION: D 65 – 23)[2]

Section 4.—Omit this section, reading as follows, renumbering the succeeding sections accordingly:

"The percentage of wear shall be not more than 12.0 per cent."

Section 6.—Change the last line of this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

"[Retained on] *Passing* 2½-in. screen . . . not [less] *more* than [85] *15* per cent."

Section 7 (*b*).—Omit this paragraph which refers to the method of testing the percentage of wear.

STANDARD SPECIFICATIONS FOR SHOVEL-RUN OR CRUSHER-RUN BROKEN SLAG FOR WATERBOUND BASE

(SERIAL DESIGNATION: D 66 – 23)[2]

Section 4.—Omit this section, reading as follows, renumbering the succeeding sections accordingly:

"The percentage of wear shall be not more than 15.0 per cent."

Section 6 (*b*).—Omit this paragraph which refers to the method of testing the percentage of wear.

STANDARD METHODS OF TESTING SHELLAC

(SERIAL DESIGNATION: D 29 – 24)[3]

A revision in the form of a separate tentative method entitled "Method of Test for Determination of Wax in Shellac (D 29 – 24 T)"[4] is intended to become a part of the present standard methods.

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[1] The quantity to be inserted in this blank space will be supplied by the committee when the information is available.

[2] 1924 Book of A.S.T.M. Standards. Criticisms of these revisions are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[3] 1924 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[4] See p. 856.

STANDARD METHODS OF TESTING OLEO-RESINOUS VARNISHES

(SERIAL DESIGNATION: D 154 – 24)[1]

A revision in the form of a separate tentative method entitled "Methods of Testing Oleo-Resinous Varnishes (D 154 – 24 T)"[2] is intended to become a part of the present standard methods.

STANDARD DEFINITIONS OF TERMS RELATING TO PAINT SPECIFICATIONS

(SERIAL DESIGNATION: D 16 – 24)[1]

Add the following two new definitions of terms:

Toughness.—Relative degree of resistance to impact without fracture; apposed to brittleness.

Elasticity of Paint and Varnish Films.—That property which allows a paint or varnish film to follow, without rupture, changes in the extent and form of the surface to which it is applied.

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[1] 1924 Book of A.S.T.M. Standards. Criticisms of these revisions are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] See p. 854.

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LIST OF STANDARDS[1]

ADOPTED BY THE

AMERICAN SOCIETY FOR TESTING MATERIALS

Published Collectively in their latest revised form in
1924 BOOK OF A.S.T.M. STANDARDS

These Standards are all copyrighted in the name of the American Society for Testing Materials. Permission to reprint any of these Standards can be obtained only from the Executive Committee on application to the Secretary-Treasurer.

The designations A 1, A 2, etc., of the Standards are fixed; the final numbers 14, 24, etc., indicate the year of adoption as standard or, in the case of revision, the year of last revision. The serial designations of Standards, which have for any reason been discontinued, are permanently dropped. In ordering Standards, the complete serial designations should be stated, thus, A 1 - 24, A 2 - 24, etc.

A. FERROUS METALS

STEEL

See also **WROUGHT IRON:** A 56 - 24)

STANDARD SPECIFICATIONS

Steel Rails and Accessories.

A 1 - 24. For Carbon Steel Rails.
A 2 - 24. For the Manufacture of Open-hearth Steel Girder Rails of Plain, Grooved and Guard Types.
A 3 - 24. For Low-Carbon-Steel Splice Bars.
A 4 - 14. For Medium-Carbon-Steel Splice Bars.
A 5 - 14. For High-Carbon-Steel Splice Bars.
A 6 - 14. For Extra-High-Carbon-Steel Splice Bars.
A 49 - 21. For Quenched High-Carbon-Steel Splice Bars.
A 50 - 24. For Quenched Carbon-Steel Track Bolts.
A 51 - 21. For Quenched Alloy-Steel Track Bolts.
A 65 - 24. For Steel Track Spikes.
A 66 - 21. For Steel Screw Spikes.

Structural Steels.

A 7 - 24. For Structural Steel for Bridges.
A 8 - 24. For Structural Nickel Steel.
A 9 - 24. For Structural Steel for Buildings.
A 10 - 24. For Structural Steel for Locomotives.
A 11 - 24. For Structural Steel for Cars.
A 12 - 21. For Structural Steel for Ships.
A 13 - 24. For Rivet Steel for Ships.

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[1] As of August 28, 1924. Total number, 220.

Spring Steel and Springs.

A 14 – 16. For Carbon-Steel Bars for Railway Springs.
A 68 – 18. For Carbon-Steel Bars for Railway Springs with Special Silicon Requirements.
A 58 – 16. For Carbon-Steel Bars for Vehicle and Automobile Springs.
A 59 – 16. For Silico-Manganese-Steel Bars for Automobile and Railway Springs.
A 60 – 16. For Chrome-Vanadium-Steel Bars for Automobile and Railway Springs.
A 61 – 16. For Helical Steel Springs for Railways.
A 62 – 16. For Elliptical Steel Springs for Railways.
A 69 – 18. For Elliptical Steel Springs for Automobiles.

Reinforcement Bars.

A 15 – 14. For Billet-Steel Concrete Reinforcement Bars.
A 16 – 14. For Rail-Steel Concrete Reinforcement Bars.

Steel Blooms, Forgings and Axles.

A 17 – 21. For Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings.
A 18 – 21. For Carbon-Steel and Alloy-Steel Forgings.
A 19 – 21. For Quenched-and-Tempered Carbon-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 63 – 21. For Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 20 – 21. For Carbon-Steel Forgings for Locomotives.
A 21 – 18. For Carbon-Steel Car and Tender Axles.
A 22 – 21. For Cold-Rolled Steel Axles.

Steel Wheels and Tires.

A 25 – 24. For Wrought Solid Carbon-Steel Wheels for Electric Railway Service.
A 57 – 24. For Wrought Solid Carbon-Steel Wheels for Steam Railway Service.
A 26 – 16. For Steel Tires.

Steel Castings.

A 27 – 24. For Steel Castings.

Steel Tubes and Pipe.

A 83 – 24. For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
A 53 – 24. For Welded and Seamless Steel Pipe.

Automobile Steels (see also **Spring Steel**).

A 29 – 24. For Automotive Carbon and Alloy Steels.

Boiler Steels.

A 30 – 24. For Boiler and Firebox Steel for Locomotives.
A 70 – 24. For Boiler and Firebox Steel for Stationary Service.
A 31 – 24. For Boiler Rivet Steel.

Bar Steels.

A 32 - 24. For Cold-Finished Bessemer Steel Automatic Screw Stock.
A 54 - 24. For Cold-Finished Open-Hearth Steel Automatic Screw Stock.
A 80 - 24. For Commercial Bar Steels.

STANDARD METHODS

A 34 - 24. Of Test for Magnetic Properties of Iron and Steel.
A 33 - 24. Of Chemical Analysis of Plain Carbon Steel.
A 55 - 24. Of Chemical Analysis of Alloy Steels.
A 90 - 24. Of Determining Weight of Coating on Zinc-Coated Articles.
A 91 - 24. Of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets.

RECOMMENDED PRACTICE

A 35 - 24. For Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects.
A 36 - 24. For Heat Treatment of Carbon-Steel Castings.
A 37 - 14. For Heat Treatment of Case-Hardened Carbon-Steel Objects.

WROUGHT IRON

(See also **STEEL:** A 83 - 24)

STANDARD SPECIFICATIONS

A 72 - 24. For Welded Wrought-Iron Pipe.
A 84 - 24. For Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars.
*A 41 - 18. For Refined Wrought-Iron Bars.
A 85 - 24. For Merchant Bar Iron.
*A 42 - 18. For Wrought-Iron Plates.
A 73 - 24. For Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars.
A 56 - 24. For Iron and Steel Chain.

STANDARD DEFINITIONS

A 81 - 21. Of Terms Relating to Wrought-Iron Specifications.

PIG IRON, CAST IRON, AND FINISHED CASTINGS

STANDARD SPECIFICATIONS

A 43 - 24. For Foundry Pig Iron.
A 44 - 04. For Cast-Iron Pipe and Special Castings.
A 74 - 18. For Cast-Iron Soil Pipe and Fittings.
A 45 - 14. For Cast-Iron Locomotive Cylinders.
A 46 - 24. For Chilled Cast-Iron Wheels.
A 47 - 24. For Malleable Castings.
A 48 - 18. For Gray-Iron Castings.
A 88 - 24. For High-Test Gray-Iron Castings.

STANDARD METHODS

A 64 - 16. Of Sampling and Chemical Analysis of Pig and Cast Iron.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

B. NON-FERROUS METALS

STANDARD SPECIFICATIONS

Ingot Copper.

*B 4 – 13. For Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.

*B 5 – 13. For Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.

Spelter.

B 6 – 18. For Spelter.

Lead.

B 29 – 23. For Pig Lead.

Nickel.

B 39 – 22. For Nickel.

Aluminum Alloys.

B 26 – 21. For Light Aluminum Casting Alloys.

Wire and Cable.

B 1 – 23. For Hard-Drawn Copper Wire.
B 2 – 15. For Medium Hard-Drawn Copper Wire.
*B 3 – 15. For Soft or Annealed Copper Wire.
B 33 – 21. For Tinned Soft or Annealed Copper Wire for Rubber Insulation.
B 8 – 21. For Bare Concentric-Lay Copper Cable: Hard, Medium-Hard, or Soft.
B 9 – 16. For High-Strength Bronze Trolley Wire, Round and Grooved: 40 and 65-per-cent Conductivity.

Bronze.

B 10 – 18. For the Alloy: Copper, 88 per cent; Tin, 10 per cent; Zinc, 2 per cent.
*B 30 – 22. For Brass Ingot Metal, Graded and Ungraded, for Sand Castings.
B 31 – 21. For Bronze Bearing Metal in Ingot Form.
B 22 – 21. For Bronze Bearing Metals for Turntables and Movable Railroad Bridges.

Solder Metal.

*B 32 – 21. For Solder Metal.

Copper and Brass Plates, Tubes, Rods, etc.

B 11 – 18. For Copper Plates for Locomotive Fireboxes.
B 12 – 21. For Copper Bars for Locomotive Staybolts.
B 13 – 18. For Seamless Copper Boiler Tubes.
B 14 – 18. For Seamless Brass Boiler Tubes.
B 44 – 24. For Seamless Admiralty Condenser Tubes and Ferrule Stock.
B 42 – 24. For Copper Pipe, Standard Sizes.
B 43 – 24. For Brass Pipe, Standard Sizes.
B 15 – 18. For Brass Forging Rod.
B 16 – 18. For Free-Cutting Brass Rod for Use in Screw Machines.
B 19 – 19. For Cartridge Brass.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

Copper and Brass Plates, Tubes, Rods, etc.—*Continued.*

B 20 - 19. For Cartridge Brass Disks.
B 21 - 19. For Naval Brass Rods for Structural Purposes.
*B 36 - 21. For High Sheet Brass.

STANDARD METHODS

*B 34 - 20. Of Battery Assay of Copper.
B 35 - 24. Of Chemical Analysis of Pig Lead.
B 38 - 21. Of Chemical Analysis of Spelter.
B 41 - 23. Of Chemical Analysis of Nickel.
*B 18 - 21. Of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper.
*B 27 - 19. Of Chemical Analysis of Manganese Bronze.
*B 28 - 19. Of Chemical Analysis of Gun Metal.
B 45 - 23. Of Chemical Analysis of Brass Ingots and Sand Castings.
B 46 - 23. Of Chemical Analysis of Bronze Bearing Metal.

C. CEMENT, LIME, GYPSUM, AND CLAY PRODUCTS

STANDARD SPECIFICATIONS

†C 9 - 21. Specifications and Tests for Portland Cement.
C 10 - 09. For Natural Cement.
C 7 - 15. For Paving Brick.
C 21 - 20. For Building Brick.
C 32 - 24. For Clay Sewer Brick.
C 13 - 24. For Clay Sewer Pipe.
C 14 - 24. For Cement-Concrete Sewer Pipe.
C 4 - 24. For Drain Tile.
C 6 - 24. For Hydrated Lime for Structural Purposes.
C 48 - 24. For Quicklime and Hydrated Lime for Use in the Textile Industry.
C 49 - 24. For Quicklime and Hydrated Lime for the Manufacture of Silica Brick.
C 23 - 22. For Calcined Gypsum.
C 28 - 21. For Gypsum Plasters.
*C 19 - 18. For Fire Tests of Materials and Construction.

STANDARD METHODS

C 16 - 20. Of Test for Refractory Materials under Load at High Temperatures.
C 20 - 20. Of Test for Porosity and Permanent Volume Changes in Refractory Materials.
C 24 - 20. Of Test for Softening Point of Fire-Clay Brick.
C 18 - 21. Of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick.
*C 29 - 21. Of Test for Unit Weight of Aggregate for Concrete.
*C 30 - 22. Of Test for Voids in Fine Aggregate for Concrete.
C 31 - 21. Of Making and Storing Specimens of Concrete in the Field.
*C 40 - 22. Of Test for Organic Impurities in Sands for Concrete.
C 41 - 24. Of Test for Sieve Analysis of Aggregates for Concrete.
C 26 - 23. Of Testing Gypsum and Gypsum Products.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

† Approved as "American Standard" by the American Engineering Standards Committee.

STANDARD DEFINITIONS

C 8 - 24. Of Terms Relating to Sewer Pipe.
C 27 - 20. For Clay Refractories.
C 43 - 24. Of Terms Relating to Hollow Tile.

RECOMMENDED PRACTICE

C 12 - 19. For Laying Sewer Pipe.

D. MISCELLANEOUS MATERIALS

PRESERVATIVE COATINGS

STANDARD SPECIFICATIONS

D 1 - 15. For Purity of Raw Linseed Oil from North American Seed.
D 11 - 15. For Purity of Boiled Linseed Oil from North American Seed.
D 13 - 24. For Turpentine.
D 125 - 23. For Perilla Oil, Raw or Refined.
D 79 - 24. For Zinc Oxide.
D 80 - 24. For Leaded Zinc Oxide.
D 81 - 24. For Basic Carbonate White Lead.
D 82 - 24. For Basic Sulfate White Lead.
D 83 - 24. For Red Lead.
D 85 - 24. For Ocher.

STANDARD METHODS

D 153 - 24. Of Test for Specific Gravity of Pigments.
D 154 - 24. Of Testing Oleo-Resinous Varnishes.
D 29 - 24. Of Testing Shellac.
*D 56 - 21. Of Test for Flash Point of Volatile Flammable Liquids.
*D 34 - 17. Of Routine Analysis of White Pigments.
*D 49 - 18. Of Routine Analysis of Dry Red Lead.
*D 50 - 18. Of Routine Analysis of Yellow, Orange, Red and Brown Pigments Containing Iron and Manganese.
D 126 - 23. Of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green.

STANDARD DEFINITIONS

D 16 - 24. Of Terms Relating to Paint Specifications.

PETROLEUM PRODUCTS AND LUBRICANTS

STANDARD METHODS

D 47 - 24. Of Test for Specific Gravity of Lubricants.
D 87 - 22. Of Test for Melting Point of Paraffin Wax.
D 92 - 24. Of Test for Flash and Fire Points by Means of Open Cup.
D 93 - 22. Of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
D 95 - 24. Of Test for Water in Petroleum Products and Other Bituminous Materials.
D 96 - 24. Of Test for Water and Sediment in Petroleum Products by Means of Centrifuge.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

ROAD MATERIALS

STANDARD SPECIFICATIONS

*D 57 – 20.	For Materials for Cement Grout Filler for Brick and Stone Block Pavements.
D 58 – 24.	For Materials for Cement Mortar Bed for Brick, Stone Block, Wood Block, Asphalt Block and Other Block Pavements.
*D 59 – 22.	For Block for Granite Block Pavements.
D 131 – 23.	For Block for Recut Granite Block Pavements.
D 132 – 23.	For Block for Durax Granite Pavements.
D 65 – 23.	For Broken Slag for Waterbound Base and Wearing Course.
D 66 – 23.	For Shovel-Run or Crusher-Run Broken Slag for Waterbound Base.

STANDARD METHODS

D 2 – 08.	Of Test for Abrasion of Road Material.
*D 3 – 18.	Of Test for Toughness of Rock.
*D 30 – 18.	Of Test for Apparent Specific Gravity of Coarse Aggregates.
D 55 – 24.	Of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials.
D 72 – 21.	Of Test for Quantity of Clay and Silt in Gravel for Highway Construction.
*D 75 – 22.	Of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods.
D 7 – 18.	Of Mechanical Analysis of Sand or Other Fine Highway Material, except Fine Aggregates Used in Cement Concrete.
D 18 – 16.	Of Mechanical Analysis of Broken Stone or Broken Slag, except Aggregates Used in Cement Concrete.
D 19 – 16.	Of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, except Aggregates Used in Cement Concrete.
D 35 – 18.	Form of Specifications for Certain Commercial Grades of Broken Stone.
*D 5 – 21.	Of Test for Penetration of Bituminous Materials.
D 6 – 20.	Of Test for Loss on Heating of Oil and Asphaltic Compounds.
*D 20 – 18.	Of Test for Distillation of Bituminous Materials Suitable for Road Treatment.
D 36 – 24.	Of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method).
D 61 – 24.	Of Test for Softening Point of Tar Products (Cube-in-Water Method).

STANDARD DEFINITIONS

D 8 – 18.	Of Terms Relating to Materials for Roads and Pavements.

COAL AND COKE

STANDARD SPECIFICATIONS

D 17 – 16.	For Foundry Coke.
D 166 – 24.	For Gas and Coking Coals.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

STANDARD METHODS

*D 21 – 16. Of Sampling Coal.
D 22 – 24. Of Laboratory Sampling and Analysis of Coal.
D 37 – 24. Of Laboratory Sampling and Analysis of Coke.
D 141 – 23. Of Shatter Test for Coke.
D 167 – 24. Of Test for Volume of Cell Space of Lump Coke.

TIMBER AND TIMBER PRESERVATIVES

STANDARD SPECIFICATIONS

D 10 – 15. For Yellow-Pine Bridge and Trestle Timbers.
D 24 – 20. For Southern Yellow-Pine Timber to be Creosoted.
D 25 – 20. For Southern Yellow-Pine Piles and Poles to be Creosoted.
D 52 – 20. For Wooden Paving Blocks for Exposed Pavements.

STANDARD METHODS

D 38 – 24. Of Sampling and Analysis of Creosote Oil.

STANDARD DEFINITIONS

D 9 – 15. Of Terms Relating to Structural Timber.

INSULATING MATERIALS

STANDARD METHODS

D 48 – 24. Of Testing Molded Insulating Materials.
D 117 – 24. Of Testing Transformer and Switch Oils.

RUBBER PRODUCTS

STANDARD SPECIFICATIONS

D 14 – 23. For Cotton Rubber-Lined Fire Hose for Private Fire Department Use.
D 26 – 23. For Cotton Rubber-Lined Fire Hose for Public Fire Department Use.
D 46 – 24. For Wrapped Air Hose for Use with Pneumatic Tools.
D 60 – 24. For Braided Air Hose for Use with Pneumatic Tools.
D 177 – 24. For Wrapped Cold Water Hose.
D 53 – 24. For Rubber Belting for Power Transmission.
D 120 – 23. For Rubber Gloves for Electrical Workers on Apparatus or Circuits Not Exceeding 3000 Volts to Ground.
D 178 – 24. For Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground.
D 151 – 23. For Rubber Pump Valves.
D 69 – 24. For Adhesive Tape for General Use for Electrical Purposes.

STANDARD METHODS

D 15 – 24. Of Testing Rubber Products.

TEXTILE MATERIALS

STANDARD METHODS

D 39 – 24. Of Testing Cotton Fabrics.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

E. MISCELLANEOUS SUBJECTS

Standard Methods

E 4 - 24. Of Verification of Testing Machines.
E 3 - 24. Of Metallographic Testing of Iron and Steel.
E 5 - 24. Of Metallographic Testing of Non-Ferrous Metals and Alloys.

Standard Rules

E 2 - 24. Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as applied to Metallography.

Standard Definitions

E 7 - 24. Of Terms Relating to Metallography.

LIST OF TENTATIVE STANDARDS[1]
PUBLISHED BY THE
AMERICAN SOCIETY FOR TESTING MATERIALS

Published Collectively in their latest revised form in
1924 BOOK OF A.S.T.M. TENTATIVE STANDARDS

Those Tentative Standards bearing the final designation of any given year are published in the annual Proceedings, Part I, of that year. Thus, Tentative Standards having the final designation "24 T" appear in this volume (see Table of contents); those having the final designation "23 T" appear in Proceedings, Vol. 23, Part I; etc.

The term "Tentative Standard" is applied to a proposed Standard which is printed in the Proceedings for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards the adoption of such Tentative Standard by formal action of the Society.

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A. FERROUS METALS
STEEL
TENTATIVE SPECIFICATIONS

A 67 - 20 T.	For Steel Tie Plates.
A 71 - 24 T.	For Carbon Tool Steel.
A 92 - 24 T.	For High-Speed Tool Steel.
A 76 - 20 T.	For Low-Carbon-Steel Track Bolts.
A 77 - 20 T.	For Electric Cast-Steel Anchor Chain.
A 78 - 23 T.	For Steel Plates of Structural Quality for Forge Welding.
A 89 - 23 T.	For Steel Plates of Flange Quality for Forge Welding.
A 82 - 21 T.	For Cold-Drawn Steel Wire for Concrete Reinforcement.
A 87 - 22 T.	For Carbon-Steel Castings for Railroads.
A 93 - 24 T.	For Hot-Dipped Galvanized Sheets.

WROUGHT IRON
TENTATIVE SPECIFICATIONS

A 86 - 21 T	For Hollow Staybolt Iron.

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[1] As of August 28, 1924. Total number, 185.

B. NON-FERROUS METALS

Tentative Specifications

B 51 – 24 T.	For Phosphor Tin.
B 52 – 24 T.	For Phosphor Copper.
B 53 – 24 T.	For Silicon Copper.
B 26 – 24 T.	For Light Aluminum Casting Alloys.[1]
B 47 – 23 T.	For Round and Grooved Hard-Drawn Copper Trolley Wire.
B 48 – 23 T.	For Soft Rectangular Copper Wire.
B 49 – 23 T.	For Hot-Rolled Copper Rods for Wire Drawing.
B 7 – 24 T.	For Manganese-Bronze Ingots for Sand Castings.
B 54 – 24 T.	For Manganese-Bronze Sand Castings.
B 55 – 24 T.	For Seamless 70–30 Brass Condenser Tubes and Ferrule Stock.
B 56 – 24 T.	For Seamless Muntz Metal Condenser Tubes and Ferrule Stock.
B 17 – 21 T.	For Non-Ferrous Alloys for Railway Equipment in Ingots, Castings, and Finished Car and Tender Bearings.
B 23 – 18 T.	For White Metal Bearing Alloys (known commercially as “Babbitt Metal”)
B 24 – 22 T.	For Aluminum Ingots for Remelting and for Rolling.
B 25 – 19 T.	For Aluminum Sheet.
B 37 – 20 T.	For Aluminum for Use in the Manufacture of Iron and Steel.
B 50 – 23 T.	For Non-Ferrous Insect Screen Cloth.

Tentative Methods

B 40 – 23 T.	Of Chemical Analysis of Aluminum and Light Aluminum Alloys.

C. CEMENT, LIME, GYPSUM, AND CLAY PRODUCTS

Tentative Specifications

C 9 – 16 T.	Specifications and Tests for Compressive Strength of Portland-Cement Mortars.[2]
C 15 – 17 T.	For Required Safe Crushing Strengths of Sewer Pipe to Carry Loads from Ditch Filling.
C 5 – 24 T.	For Quicklime for Structural Purposes.
C 45 – 24 T.	For Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper.
C 46 – 24 T.	For Quicklime for Use in the Manufacture of Sulfite Pulp.
C 47 – 22 T.	For Hydrated Lime for the Manufacture of Varnish.
C 53 – 24 T.	For Quicklime for Use in Water Treatment.
C 54 – 24 T.	For Hydrated Lime for Use in Water Treatment.
C 33 – 23 T.	For Concrete Aggregates.
C 55 – 24 T.	For Concrete Building Brick.
C 34 – 24 T.	Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile.
C 56 – 24 T.	Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile.
C 57 – 24 T.	Specifications and Tests for Hollow Burned-Clay Floor Tile.
C 22 – 24 T.	For Gypsum.

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[1] To replace, when adopted, the Standard Specifications for Light Aluminum Casting Alloys (Serial Designation: B 26–21.)

[2] To be added, when adopted, to the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9 – 21).

C 35 – 24 T.	For Gypsum Plastering Sand.
C 36 – 24 T.	For Gypsum Wall Board.
C 37 – 22 T.	For Gypsum Plaster Board.
C 52 – 24 T.	For Gypsum Partition Tile or Block.

Tentative Methods

C 25 – 22 T.	Of Chemical Analysis of Limestone, Quicklime and Hydrated Lime.
C 50 – 24 T.	Of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products.
C 17 – 19 T.	Of Test for Slagging Action of Refractory Materials.
C 38 – 21 T.	Of Test for Resistance of Fire-Clay Brick to Spalling Action.
C 39 – 21 T.	Of Making Compression Tests of Concrete.
C 42 – 21 T.	Of Securing Specimens of Hardened Concrete from the Structure.

Tentative Definitions

C 51 – 24 T.	Of Terms Relating to Lime.
C 11 – 24 T.	Of Terms Relating to the Gypsum Industry.
C 58 – 24 T.	Of the Term Sand.

Tentative Rules

C 44 – 22 T.	For Inspection of Concrete and Reinforced Concrete Work.

D. MISCELLANEOUS MATERIALS

PRESERVATIVE COATINGS

Tentative Specifications

D 12 – 23 T.	For Raw Tung Oil.
D 124 – 22 T.	For Soya Bean Oil, Raw or Refined.
D 51 – 18 T.	For Foots Permissible in Properly Clarified Pure Raw Linseed Oil from North American Seed.
D 77 – 21 T.	For Purity of Raw Linseed Oil from South American Seed.
D 78 – 21 T.	For Purity of Boiled Linseed Oil from South American Seed.
D 84 – 24 T.	For Iron Oxide and Iron Hydroxide.

Tentative Methods

D 154 – 24 T.	Of Testing Oleo-Resinous Varnishes.[1]
D 29 – 24 T.	Of Test for Determination of Wax in Shellac.[2]
D 185 – 24 T.	Of Test for Coarse Particles in Paint Pigments.
D 186 – 24 T.	Of Routine Analysis of Titanium Pigments.

PETROLEUM PRODUCTS AND LUBRICANTS

Tentative Methods

D 86 – 24 T.	Of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products.
D 127 – 24 T.	Of Test for Melting Point of Petrolatum.

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[1] To be added, when adopted, to the present Standard Methods of Testing Oleo-Resinous Varnishes (Serial Designation: D 154 – 24).

[2] To be added, when adopted, to the present Standard Methods of Testing Shellac (Serial Designation: D 29 – 24).

D 128 – 24 T.	Of Analysis of Grease.
D 88 – 24 T.	Of Test for Viscosity of Petroleum Products and Lubricants.
D 155 – 23 T.	Of Test for Color of Lubricating Oils by Means of Union Colorimeter.
D 156 – 23 T.	Of Test for Color of Refined Petroleum Oil by Means of Saybolt Chromometer.
D 187 – 24 T.	Of Test for Burning Quality of Kerosene Oils.
D 90 – 24 T.	Of Test for Sulfur in Naphthas and Illuminating Oils.
D 129 – 22 T.	Of Test for Sulfur in Petroleum Oils Heavier than Illuminating Oil.
D 130 – 22 T.	Of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline.
D 91 – 21 T.	Of Test for Precipitation Number of Lubricating Oils.
D 157 – 23 T.	Of Test for Steam Emulsion of Lubricating Oils.
D 94 – 21 T.	Of Test for Saponification Number.
D 188 – 24 T.	Of Test for Free Acid in Lubricants.
D 189 – 24 T.	Of Test for Carbon Residue of Lubricants.
D 97 – 23 T.	Of Test for Cloud and Pour Points of Petroleum Products.
D 158 – 23 T.	Of Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water).

ROAD MATERIALS

TENTATIVE SPECIFICATIONS

D 63 – 23 T.	For Commercial Sizes of Broken Stone and Broken Slag for Highway Construction.
D 64 – 20 T.	For Commercial Sizes of Sand and Gravel for Highway Construction.
D 190 – 24 T.	For Broken Stone for Waterbound Base.
D 191 – 24 T.	For Broken Stone for Waterbound Macadam Surface Course.
D 192 – 24 T.	For Broken Stone for Bituminous Macadam.
D 193 – 24 T.	For Broken Stone for Bituminous Concrete Base.
D 194 – 24 T.	For Broken Stone for Bituminous Concrete Surface.
D 195 – 24 T.	For Broken Slag for Bituminous Macadam Base.
D 196 – 24 T.	For Broken Slag for Bituminous Concrete Base.
D 159 – 24 T.	For Broken Slag for Bituminous Macadam Wearing Course.
D 160 – 24 T.	For Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type).
D 161 – 24 T.	For Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type).
D 162 – 23 T.	For Sand for Sheet Asphalt and Bituminous Concrete Pavements.
D 67 – 23 T.	For Natural or Artificial Sand-Clay Mixtures for Road Surfacing.
D 98 – 22 T.	For Calcium Chloride for Dust Prevention.
D 133 – 23 T.	For Asphalt Cement, 10 to 15 Penetration, for the Manufacture of Asphalt Block.
D 134 – 23 T.	For Asphalt Cement, 15 to 25 Penetration, for the Manufacture of Asphalt Block.
D 163 – 23 T.	For Asphalt Cement, 25 to 30 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements.

D 164 - 23 T.	For Asphalt Cement, 30 to 40 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements.
D 99 - 23 T.	For Asphalt Cement, 40 to 50 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements.
D 100 - 23 T.	For Asphalt Cement, 50 to 60 Penetration, for Use in Sheet Asphalt and Asphaltic Concrete Pavements.
D 101 - 23 T.	For Asphalt Cement, 60 to 70 Penetration, for Use in Sheet Asphalt, Asphaltic Concrete, and Asphalt Macadam Pavements.
D 102 - 24 T.	For Asphalt Cement, 85 to 100 Penetration, for Use in Asphalt Macadam Pavements.
D 103 - 24 T.	For Asphalt Cement, 100 to 120 Penetration, for Use in Asphalt Macadam Pavements.
D 135 - 23 T.	For Asphalt Cement, 120 to 150 Penetration, for Use in Asphalt Macadam Pavements.
D 104 - 23 T.	For High-Carbon Tar for Surface Treatment, Cold Application.
D 105 - 23 T.	For Low-Carbon Tar for Surface Treatment, Cold Application.
D 106 - 23 T.	For High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).
D 107 - 23 T.	For Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).
D 108 - 23 T.	For High-Carbon Tar for Surface Treatment, Hot Application.
D 109 - 23 T.	For Low-Carbon Tar for Surface Treatment, Hot Application.
D 110 - 23 T.	For High-Carbon Tar Cement.
D 111 - 23 T.	For Low-Carbon Tar Cement.
D 112 - 23 T.	For Coal-Tar Pitch for Stone Block Filler.

TENTATIVE METHODS

D 70 - 20 T.	Of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches.
D 71 - 20 T.	Of Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments.
D 73 - 20 T.	Of Test for Quantity of Clay in Sand-Clay, Topsoil and Semi-Gravel for Highway Construction.
D 136 - 22 T.	Of Decantation Test for Sand and Other Fine Aggregates.
D 137 - 24 T.	Of Mechanical Analysis of Subgrade Soils.
D 138 - 22 T.	Of Test for Consistency of Portland-Cement Concrete for Pavements or for Pavement Base.
D 4 - 23 T.	Of Test for the Determination of Bitumen.
D 165 - 23 T.	Of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride.
D 113 - 22 T.	Of Test for Ductility of Bituminous Materials.
D 139 - 24 T.	Of Float Test for Bituminous Materials.
D 140 - 23 T.	Of Sampling Bituminous Materials.

COAL AND COKE

TENTATIVE METHOD

D 197 - 24 T.	Of Test for Fineness of Powdered Coal.

TENTATIVE DEFINITIONS

D 121 - 24 T.	Of Terms Relating to Coke.
D 142 - 24 T.	Of Terms Relating to Coal.

TIMBER

TENTATIVE SPECIFICATIONS

D 23 - 20 T.	For Structural Douglas Fir.

TENTATIVE METHODS

D 143 - 24 T.	Of Testing Small Clear Specimens of Timber.
D 198 - 24 T.	For Conducting Static Tests of Timbers in Structural Sizes.
D 168 - 23 T.	Of Test for Coke Residue of Creosote Oil.[1]
D 199 - 24 T.	Of Chemical Analysis of Zinc Chloride.

WATERPROOFING

TENTATIVE SPECIFICATIONS

D 40 - 24 T.	For Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level.
D 144 - 24 T.	For Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level.
D 41 - 22 T.	For Primer for Use with Asphalt in Damp-proofing and Waterproofing Below and Above Ground Level.
D 42 - 24 T.	For High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.
D 145 - 24 T.	For High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 200 - 24 T.	For High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.
D 201 - 24 T.	For High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 43 - 22 T.	For Creosote Oil for Priming Coat with Coal-Tar Pitch in Damp-proofing and Waterproofing Below and Above Ground Level.
D 169 - 24 T.	For Asphalt Mastic for Use in Waterproofing.
D 170 - 24 T.	For Bituminous Grout for Use in Waterproofing Above Ground Level.
D 171 - 24 T.	For Bituminous Grout for Use in Waterproofing Below Ground Level.
D 172 - 23 T.	For Felted Fabrics Saturated with Bituminous Substances for Use in Waterproofing.
D 173 - 23 T.	For Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing.
D 174 - 23 T.	For Burlap Saturated with Bituminous Substances for Use in Waterproofing.

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[1] To be added, when adopted, to the present Standard Methods of Sampling and Analysis of Creosote Oil (Serial Designation: D 38 - 24).

TENTATIVE METHODS

D 146 - 23 T.	Of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing.
D 147 - 24 T.	Of Testing Bituminous Mastics, Grouts and Like Mixtures.

INSULATING MATERIALS

TENTATIVE METHODS

D 115 - 24 T.	Of Testing Insulating Varnishes.
D 116 - 24 T.	Of Testing Electrical Porcelain.
D 149 - 24 T.	Of Testing Sheet and Tape Insulating Materials for Dielectric Strength.
D 150 - 23 T.	Of Testing Electrical Insulating Materials for Phase Difference (Power Factor) and Dielectric Constant at Radio Frequencies.
D 175 - 23 T.	Of Testing Electrical Insulating Materials for Voltage Effects at Radio Frequencies.
D 176 - 24 T.	Of Testing Cable Splicing and Pothead Compounds.
D 202 - 24 T.	Of Testing Untreated Insulating Paper.

SHIPPING CONTAINERS

TENTATIVE SPECIFICATIONS

D 44 - 20 T.	For Wooden Boxes, Nailed and Lock-Corner Construction, for the Shipment of Canned Foods.
D 45 - 17 T.	For Canned Foods Boxes, Wirebound Construction.
D 68 - 22 T.	For Wooden Boxes, Nailed and Lock-Corner Construction.
D 118 - 21 T.	For 4-One Boxes and Similar Type Boxes.

RUBBER PRODUCTS

TENTATIVE SPECIFICATIONS

D 27 - 21 T.	For Insulated Wire and Cable: 30-per-cent Hevea Rubber.
D 54 - 24 T.	For Steam Hose.
D 119 - 22 T.	For Rubber Insulating Tape.

TEXTILE MATERIALS

TENTATIVE SPECIFICATIONS

D 76 - 22 T.	For Textile Testing Machines.
D 122 - 23 T.	For Imperfections and Tolerances for Square-Woven Tire Fabrics.
D 179 - 23 T.	For Imperfections and Tolerances for Cord Tire Fabrics.
D 181 - 24 T.	For Tolerances for Hose Ducks and Belt Ducks.
D 180 - 24 T.	For Tolerances and Test Methods for Cotton Yarns, Single and Plied.
D 203 - 24 T.	For Tolerances and Test Methods for Electrical Cotton Yarns.
D 204 - 24 T.	For Tolerances and Test Methods for Cotton Sewing Threads.
D 205 - 24 T.	Specifications and Tests for Osnaburg Cement Sacks.

TENTATIVE METHODS

D 152 - 22 T.	Of Testing Cotton Fibers.

TENTATIVE DEFINITIONS

D 123 - 22 T.	Of Terms Relating to Textile Materials.

THERMOMETERS

TENTATIVE SPECIFICATIONS

D 182 - 23 T.	For A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F.
D 183 - 23 T.	For A.S.T.M. Partial-Immersion Thermometer for General Use, −5 to +300° C., +20 to +580° F.
D 184 - 23 T.	For A.S.T.M. Partial-Immersion Thermometer for General Use, −5 to +400° C., +20 to +760° F.

E. MISCELLANEOUS SUBJECTS

TENTATIVE METHODS

E 8 - 24 T.	Of Tension Testing of Metallic Materials.
E 9 - 24 T.	Of Compression Testing of Metallic Materials.
E 10 - 24 T.	Of Brinell Hardness Testing of Metallic Materials.
E 4 - 24 T.	Of Verification of Testing Machines by Means of an Elastic Calibration Bar.[1]

TENTATIVE DEFINITIONS

E 6 - 24 T.	Of Terms Relating to Methods of Testing.

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[1] To be added, when adopted, to the present Standard Methods of Verification of Testing Machines (Serial Designation: E 4–24.)